Short Communication


Pulmonary Circulation during Exercise in Rats

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Summary  Pulmonary arterial pressure of treadmill-running rats became significantly higher than the sedentary control level, while systemic arterial pressure did not rise. The rise of pulmonary arterial pressure seemed to be accompanied with the increase of cardiac output.

Key words:  pulmonary arterial pressure, exercise.

Hearts of humans and animals who live in high-altitude environments show cardiac hypertrophy. Especially the right ventricle shows a greater hypertrophy than the left one (Reeves et al., 1979; Sakai et al., 1977). In a long-term athletic training, also, cardiac hypertrophy—or so-called athletic heart—takes place. It is not yet clarified, however, whether the development of high-altitude hypertrophy and that of athletic hypertrophy are based on a common mechanism. The present investigation was designed to study the pulmonary circulation during exercise in rats as a way of elucidating the mechanism of the athletic heart. Some reports on pulmonary circulation during exercise were presented on humans and sheep (Newman et al., 1986; 1988; Kawashima et al., 1989), but no report has been presented so far in small animals like rats. Surgical operation performed in this experiment is difficult, but once completed, various experiments can be made under designed conditions. The mechanism for the development of pulmonary hypertension during exercise may be clarified, and the results will be useful in the research field of sports medicine.

Twenty Wistar-strain rats (240–278 g) were anesthetized intramuscularly with ketamine (9 mg/100 g body weight). A polyvinyl catheter (PV1, internal diameter 0.28 mm) with a shallow bend at its tip was inserted into the right jugular vein and guided into the main pulmonary artery. The location of the catheter was verified by the characteristic pulmonary-artery-pressure tracing displaced on an oscilloscope. After the pulmonary artery catheter was in place, a second catheter (PE-50, internal...

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diameter 0.58 mm) was placed in the right carotid artery. Each catheter was filled with heparinized saline and connected with a blood pressure transducer (Statham P-50, Oxford, CA) for measurement of systemic arterial pressure \( P_{SA} \) via the carotid artery catheter) and pulmonary arterial pressure \( P_{PA} \) via the pulmonary arterial catheter). After placement, the catheters were tied to prevent backflow and were tunneled subcutaneously to the back of the neck. The catheters were protected in a plastic housing sutured to the skin and covered with a rubber cap (CHANG et al., 1987). The following day, while the rats were put on a treadmill, the systemic and pulmonary arterial pressure were measured during exercise. The treadmill speed was started at 10 and increased stepwise to 20, 25, 30, and 35 m/min, with rats resting between serial steps. Exercise was interrupted in 6 rats that showed apparent features of exhaustion. The \( P_{SA} \) and \( P_{PA} \) values between before and during exercises were compared at each load. Data were expressed as the mean ± S.E. Statistical analysis was made for paired data by Student’s t-test.

Figure 1 shows recordings during 1 min 40 s exercise at 25 m/min. During the exercise, \( P_{PA} \) rose gradually from 17 to 25 mmHg. After the exercise, it fell by degrees to the control level observed before each exercise. \( P_{SA} \) is plotted against the speed of the exercise in Fig. 2; \( P_{SA} \) values were measured in the range of 10 to 35 m/min, but the difference was insignificant. Figure 3 shows readings of \( P_{PA} \); \( P_{PA} \) levels during the exercise were significantly higher than those of the controls \( p < 0.01 \). In the former, \( P_{PA} \) rose suddenly at 30 m/min.

It is well known that \( P_{PA} \) rises significantly under exposure to high-altitude

![Graph of Systemic Arterial Pressure and Pulmonary Arterial Pressure](image)

**Fig. 1.** Recordings of systemic and pulmonary arterial pressure during exercise.

Treadmill speed was set to 25 m/min for 1 min 40 s.

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Fig. 2. Systemic arterial pressure during exercise versus treadmill speed. Values are mean ± S.E. ●, during exercise; ○, controls.

Fig. 3. Pulmonary arterial pressure during exercise versus treadmill speed. Values are mean ± S.E. *p < 0.01. ●, during exercise; ○, controls.

environments, such as hypoxia, hypobaria, and cold. When the living body is exposed to these conditions, pulmonary small vessels tend to constrict (Reeves et al., 1979) and the resistance of pulmonary circulation rises. Regarding exercise,
measurements of $P_{PA}$ in humans and sheep have been reported, but the reports disagree with each other. Hickman and Cargill (1948) reported that $P_{PA}$ fell during light and heavy exercises. Kawashima et al. (1989) reported that $P_{PA}$ rose clearly during load of light exercise (25 W, 50 W). Newman et al. (1986, 1988) observed that $P_{PA}$ rose in sheep when using a treadmill. In the present study $P_{PA}$ showed high values compared with controls during exercise (Figs. 1 and 3). Over 25 m/min $P_{PA}$ rose clearly during the load of exercise. Generally, cardiac output increases during exercise, so the rise of $P_{PA}$ shown in this experiment was considered to be caused by the increase of cardiac output. In fact, Hickman and Cargill (1948) and Kawashima et al. (1989) reported that the resistance of pulmonary circulation decreased significantly according to the load of exercise. What is remarkable here is that $P_{PA}$ rose significantly according to the load of exercise, but $P_{SA}$ showed no change. This result indicates that the work-rate ratio of the right ventricle to the left ventricle changed. When this sort of state continues for a long time, it seems possible that the right ventricle is altered gradually from a state of normotrophy to hypertrophy. The present study seems to be consistent with the report of Van Liere et al. (1965), who confirmed the development of right cardiac hypertrophy in rats that were forced to exercise on treadmill running at a speed of 1 mile/h for 2 h a day, for a total 60 h of treadmill run.

REFERENCES


