Exercise pressor reflex in decerebrate and anesthetized rats

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Hayashi, Naoyuki. Exercise pressor reflex in decerebrate and anesthetized rats. Am J Physiol Heart Circ Physiol 284: H2026–H2033, 2003.—I investigated whether muscular contraction evokes cardiorespiratory increases (exercise pressor reflex) in α-chloralose- and chloral hydrate-anesthetized and precollicular, midcollicular, and postcollicular decerebrated rats. Mean arterial pressure (MAP), heart rate (HR), and minute ventilation (VE) were recorded before and during 1-min sciatic nerve stimulation, which induced static contraction of the triceps surae muscles, and during 1-min stretch of the calcaneal tendon, which selectively stimulated mechanosensitive receptors in the muscles. Anesthetized rats showed various patterns of MAP response to both stimuli, i.e., biphasic, depressor, pressor, and no response. Sciatic nerve stimulation to muscle in precollicular decerebrated rats always evoked spontaneous running, so the exercise pressor reflex was not determined from these preparations. None of the postcollicular decerebrated rats showed a MAP response or spontaneous running. Midcollicular decerebrated rats consistently showed biphasic blood pressure response to both stimulations. The increases in MAP, HR, and VE were related to the tension developed. The static contractions in midcollicular decerebrated rats (381 ± 65 g developed tension) significantly increased MAP, HR, and VE from 103 ± 21 to 119 ± 24 mmHg, from 386 ± 30 to 406 ± 83 beats/min, and from 122 ± 7 to 133 ± 25 mL/min, respectively. After paralysis, sciatic nerve stimulation had no effect on MAP, HR, or VE. These results indicate that the midcollicular decerebrated rat can be a model for the study of the exercise pressor reflex.

mechanosensitive receptors; metabosensitive receptors; mean arterial pressure; static contraction

INFORMATION ABOUT MECHANICAL and metabolic changes in exercising skeletal muscles is conducted by group III and IV afferent nerves and functions to increase heart rate (HR), mean arterial pressure (MAP), and minute ventilation (VE) through medullary pathways (13). This is called an exercise pressor reflex.

Rats are often used in the study of cardiorespiratory physiology and neurophysiology. A pressor response to static and dynamic exercise was observed in intact and conscious rats (4, 7, 30). Detailed data concerning the pathway of the exercise pressor reflex have been reported (3, 14, 19, 33). Also, numerous studies have reported on hemodynamic changes with aging, physical training, and detraining (29, 31), partly because it is easier to observe aging and training effects in rats than in larger animals. Furthermore, the rat as a disease model, such as in hypertension and diabetes, is used for cardiovascular study (29, 30, 31). If a model for the exercise pressor reflex is to be useful, the response should be the same as that obtained from intact, conscious rats. However, there is no consistent evidence for the exercise pressor reflex in anesthetized rats (14), indicating that these models are not applicable to study of the effects of aging, physical training, detraining, and disease on the exercise pressor reflex as yet.

Previous studies using rats reported that the blood pressure response to static contraction or to muscle stretch elicited no change (34), an increase (2, 19, 32), or a decrease (15, 22, 32). These different responses were attributed to the different anesthetics, which include pentobarbital (2, 19, 32), chloral hydrate (2, 19), halothane (27), and α-chloralose (16, 22, 34). Only two studies used a decerebrate preparation, and both showed consistent pressor reflex response to muscle contraction (23, 27). Decerebration in rats is more difficult than anesthesia and also more difficult than in cats because relatively more blood is lost during surgical procedure than in cats. Therefore, if some type of anesthesia allowed the exercise pressor reflex to be expressed in rats, it would be more convenient to apply and would improve the success rate of experiments. However, there is limited information about the effect of anesthesia on the exercise pressor reflex in rats. In the present study, α-chloralose and chloral hydrate were selected as the anesthetics because the former is often used in cat preparations for studies of the pressor reflex (10, 11, 36) and previous studies reported consistent pressor reflex in chloral hydrate-anesthetized rats (2, 19).

Decerebrate rats have been shown to display a pressor reflex in response to contraction and stretching of the muscles in the forelimb as well as in the hindlimb (23, 27). In those studies, precollicular decerebration was performed. In cats, the level of decerebration has been reported to affect the magnitude of the reflex (13). It is possible that the level of decerebration in rats has a similar effect on the pressor reflex, implying the possibility of improvement of the decerebrate rat model. In addition, the forelimb has been reported to
evoke a greater reflex response than the hindlimb in cats (10). Moreover, Potts et al. (23) succeeded in observing the pressor reflex by stimulating the forelimb muscle. It was anticipated that it might be easier to evoke the pressor reflex in rats as well as cats by using the forelimb.

In developing a rat model for studying cardiovascular control during exercise, the aims of this study were 1) to reinvestigate whether decerebrated rats are an appropriate model for the exercise pressor reflex, 2) to investigate the effect of two frequently used anesthetics (α-chloralose and chloral hydrate) on the exercise pressor reflex, 3) to characterize the reflex in decerebrated rats, and 4) to examine whether the forelimb or hindlimb evokes the greater pressor reflex.

METHODS

General. All experimental procedures were approved by the Institutional Animal Care and Use Committee and were conducted in accordance with the American Physiological Society’s “Guiding Principles for Research Involving Animals and Human Beings.” Sprague-Dawley rats of either sex (310–420 g) were anesthetized with a mixture of halothane (4%) and oxygen. The rats were divided into five groups according to anesthetic (α-chloralose and chloral hydrate) and level of decerebration (pre-, mid-, and postcollicular levels). Anesthesia was maintained by halothane in the decerebrate preparation and by α-chloralose or chloral hydrate in the anesthetized rats. The trachea, the jugular vein, and a common carotid artery were cannulated. A pneumotachograph was placed in series with the trachea cannula. The pneumotachograph was, in turn, attached to a differential pressure transducer (DPM45-24) to measure ventilation. The carotid catheter was attached to a Statham P23XL transducer to measure arterial pressure. HR was calculated beat by beat with a Gould Biotach. Arterial blood gases and pH were measured at 1-h intervals on a Radiometer blood gas analyzer (ABL 3). These were maintained within normal limits by infusing sodium bicarbonate solution intravenously or by adding oxygen (P O2 > 90 mmHg) to the trachea cannula. Body temperature was maintained between 37 and 38°C.

The triceps surae muscles were isolated. The origin of the muscles was left intact. The calcaneal bone was severed and attached to a force transducer (FT-03; Grass). The nerves supplying the left triceps surae muscles were exposed. The skin flaps were attached to bars to form a pool, which was filled with warm mineral oil. All visible nerves, except for those innervating the triceps surae, were cut. The triceps brachii muscles were also exposed. All visible nerves, except for those innervating the triceps brachii, were cut. The tendon attaching the triceps brachii to the elbow was cut and attached to the force transducer. Clamps were placed on the elbow and shoulder.

Anesthetized preparations. Before the surgery started, anesthesia was changed to α-chloralose (50 mg/kg iv) in eight rats and to chloral hydrate (150 mg/kg ip) and pentobarbital sodium (25 mg/kg ip) in six rats. The halothane was gradually reduced as these anesthetic agents took effect. To maintain anesthesia, supplemental doses of α-chloralose (5 mg/kg iv) and chloral hydrate (25 mg/kg ip) were given when either corneal reflex or forelimb pinch evoked a response in movement, MAP, or Vé.

Decerebrate preparations. Decerebration was performed in 18 rats. In these rats, after induction of anesthesia by halothane, 1–2% halothane was used to maintain anesthesia. Decerebration was done with a method similar to that described by Sapru and Krieger (25) and Smith et al. (27), except that the brain was sectioned not only at the precollicular level in four rats but also at the midcollicular level in seven rats and at the postcollicular level in seven rats. Dexamethasone (0.2 mg) was given intravenously to minimize edema. Immediately before the decerebration, both common carotid arteries were occluded. Cortical tissue over colliculi was aspirated. The brain was then sectioned with a blade at the pre-, mid-, or postcollicular level. All neural tissue rostral to the section as well as the cortical tissues covering the cerebellum were aspirated (Fig. 1). Immediately after the decerebration, the halothane anesthesia was stopped. To replace the blood lost during decerebration (approximately <1 ml), saline was given intravenously in an amount sufficient to maintain basal arterial pressure. A recovery period of 2 h was allowed to eliminate the effect of halothane and to stabilize the preparation.

In addition, the level of decerebration was progressively changed in two of the four precollicular decerebrated rats, that is, three levels of decerebration were applied to the same rat, to confirm that the effect of decerebration was similar to that obtained from single-level decerebration. During the surgery between progressive decerebration, halothane (1–2%) was mixed into the inspired oxygen; otherwise, the rat often started running. Whereas the data obtained during precollicular decerebration were used for the data of the precollicular decerebrate group, the data obtained during mid- and postcollicular decerebration were observed but not used for further analysis to avoid any confounding effect, e.g., long elapsed time for additive surgery.

Protocols. To activate both mechanically and metabolically sensitive receptors, static contraction was induced by stimu-

![Fig. 1. Schema of the levels of decerebration. The levels of pre-, mid- and postcollicular decerebrations are shown. The arrow in the horizontal image indicates what the sagittal view illustrates, and the arrow in the sagittal image indicates what the horizontal view illustrates. CA, hippocampal area; CdP, caudoputamen; DG, dentate gyrus; ENT, entorhinal area; IC, inferior colliculus; LV, lateral ventricle; NTS: nucleus tractus solitarii; Pí, pineal gland; PPT, pedunculopontine tegmental nucleus; SC, superior colliculus; SN, substantia nigra; VLM, ventrolateral medulla.](image-url)
lating the sciatic nerve for 1 min (40 Hz; 0.02 5 ms; <3× motor threshold). To selectively stimulate mechanically sensitive receptors in muscles, the triceps surae and triceps brachii were passively stretched for 1 min. More than three different magnitudes of tension were evoked by hindlimb stimulation if no spontaneous behavior was observed. The muscles were preloaded at 50–100 g tension in the hindlimb and 20–50 g tension in the forelimb before the trials (control period).

After completing the contraction protocols, I determined that the responses were not mediated by direct electrical activation of afferents during the trials. Therefore, the neuromuscular blocking agent (rocuronium bromide; 0.1 mg iv) was given and then the sciatic nerve was stimulated at the same parameters as in the trials. Also, after the sciatic nerve was sectioned, the triceps surae muscle was passively stretched at the same tension as in the trial and the central end of the nerve was stimulated in the same way. Furthermore, to determine that the brain stem and spinal regions relevant to the responses were intact, the nerve was stimulated at an intensity of 10 times the motor threshold. These stimulation parameters electrically activated group III muscle afferent fibers (21, 24).

Data analysis. Changes in MAP, HR, and $\dot{V}E$ were plotted against developed tension. All values are expressed as means ± SE. Statistical analysis was performed by repeated-measure analysis of variance to investigate the effect of developed tension on the responses, and a post hoc Scheffe's test was used to determine whether the response was significant. The criterion level for significance was set at $P < 0.05$.

RESULTS

$Pc_{O_2}$ and pH were maintained within normal values except for the postcollicular decerebrated preparation during contraction and stretch trials (Table 1). It was impossible to maintain a normal level of $Pc_{O_2}$ in the postcollicular decerebrated group. The weight of the triceps surae muscles was not different among groups of anesthesia and levels of decerebration.

Different blood pressure patterns of response to both contraction and stretch were observed. The blood pressure responses to the two stimuli were categorized into six characteristic patterns, as shown in Fig. 2. The anesthetized rats showed varied responses, i.e., categories A, B, C, and E in Fig. 2. The number of rats showing each response in Fig. 2 is presented in Table 2.

In the chloral hydrate-anesthetized rats, different patterns to the same type of stimulus were observed; consequently, the total number of chloral hydrate-anesthetized rats in Table 2 does not equal the total number of preparations. The response patterns in the forelimb were similar to those in the hindlimb. No spontaneous movement was observed in the anesthetized rats.

Postcollicular decerebrated rats showed spontaneous running behavior not only during contraction but also sometimes during the control period. The spontaneous running is shown as the rhythmic contraction of category $E$ in Fig. 2. All midcollicular decerebrated rats showed category $A$, which was biphasic response, whereas they sometimes showed spontaneous running during the contraction period (category $E$). None of the postcollicular decerebrated rats showed a pressor response or spontaneous running. The progressively decerebrated rats showed the same response pattern as observed in each level of decerebration, i.e., category $E$ after precollicular decerebration, categories $A$ and $E$ after midcollicular decerebration, and then category $C$ after postcollicular decerebration.

After the sciatic nerve was sectioned, when the triceps surae muscle was pulled at the same tension as was done in the trial, the blood pressure and ventilatory responses to stimulation were abolished (similar to category $C$ in Fig. 2). Likewise, after the nerve was cut, when the central cut end of the sciatic nerve was stimulated at the same parameters as before the nerve was cut (40 Hz; 0.025 ms; <3× motor threshold), the blood pressure and ventilatory responses to stimulation were abolished (similar to category $C$ in Fig. 2, but tension was not generated). After paralysis with rocuronium, the responses to the stimulation at the same parameters described above were abolished. In addition, stimulation at the intensity of 10 times the motor threshold was performed to examine whether or not the regions relevant to the responses were intact. MAP, HR, and $\dot{V}E$ responses were observed in all rats even after nerve sectioning and paralysis (category $D$, Fig. 2).

The MAP, HR, and $\dot{V}E$ responses to contraction and stretch are summarized in Table 3. The value in each rat was obtained from the trial in which the largest tension was generated by or applied to the muscle and no spontaneous running was observed. If spontaneous running was observed the data were discarded, because it was impossible to distinguish the reflex response from the response to central command. No data of precollicular decerebrated rats are shown in Table 3 because they always showed spontaneous behavior during the trial. The anesthetized rats showed no significant increase in these variables. The midcollicular decerebrated rats showed significant increases in

<table>
<thead>
<tr>
<th>Anesthesia/Decerebration</th>
<th>$n$</th>
<th>Triceps Surae Weight, g</th>
<th>Triceps Brachii Weight, g</th>
<th>Arterial $Pc_{O_2}$, mmHg</th>
<th>Arterial pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$-Chloralose</td>
<td>8</td>
<td>$2.72 \pm 0.13$</td>
<td>$1.62 \pm 0.13$</td>
<td>$43.1 \pm 5.7$</td>
<td>$7.35 \pm 0.06$</td>
</tr>
<tr>
<td>Chloral hydrate</td>
<td>6</td>
<td>$2.62 \pm 0.12$</td>
<td>$1.68 \pm 0.08$</td>
<td>$41.2 \pm 3.2$</td>
<td>$7.36 \pm 0.02$</td>
</tr>
<tr>
<td>Precollicular</td>
<td>4</td>
<td>$2.33 \pm 0.15$</td>
<td>$1.58 \pm 0.10$</td>
<td>$33.1 \pm 3.5$</td>
<td>$7.45 \pm 0.04$</td>
</tr>
<tr>
<td>Midcollicular</td>
<td>7</td>
<td>$2.52 \pm 0.07$</td>
<td>$1.60 \pm 0.05$</td>
<td>$40.9 \pm 3.2$</td>
<td>$7.37 \pm 0.03$</td>
</tr>
<tr>
<td>Postcollicular</td>
<td>7</td>
<td>$2.71 \pm 0.16$</td>
<td>$1.72 \pm 0.07$</td>
<td>$23.6 \pm 4.8$</td>
<td>$7.45 \pm 0.04$</td>
</tr>
</tbody>
</table>

Values are means ± SE.
MAP, HR, and $\dot{V}E$ to contraction and stretch from control value.

The time course of MAP responses to stretch and contraction in midcollicular decerebrated rats is shown in Fig. 3. All midcollicular decerebrated rats showed a similar biphasic pattern. The MAP peak occurred 5–20 s after the start of both stretch and contraction.

Peak change in MAP, HR, $\dot{V}E$, and respiratory rate was plotted against developed tension during stretch and contraction (Fig. 4). ANOVA revealed that developed tension significantly affected the MAP, HR, and $\dot{V}E$ responses but not the respiratory rate. Changes in MAP during both contraction and stretch were related to developed tension. The change in HR during contraction was also related to developed tension, whereas the change during stretch was not related to developed tension. $\dot{V}E$ was also related to developed tension, but large variation was seen in the response to low tension levels during stretch. Change in respiratory rate was not related to developed tension.

In midcollicular decerebrated rats, stretch and contraction of the forelimb were tried. However, only a small number of data at low developed tension stimulus were obtained because spontaneous movement was often observed; it was always observed when developed tension exceeded 200 g to the forelimb. The results obtained from three rats are plotted in Fig. 4.

**DISCUSSION**

The main findings in the present study were that 1) midcollicular decerebrated rats showed consistent biphasic MAP responses and significant increases in MAP, HR, and $\dot{V}E$ to both muscle contraction and stretch; 2) the MAP and HR increases were related to the magnitude of the stimuli applied to the muscle; and 3) anesthetized rats showed varied MAP responses. These findings lead to the conclusion that the midcollicular decerebrated rat is an appropriate model for investigating the exercise pressor reflex.

**Decerebrated rats.** The present study and previous studies clearly show that the decerebrated rat, but not the anesthetized rat, is an appropriate model for the
Table 3. MAP, HR, and $V_E$ responses to contraction and tendon stretch

<table>
<thead>
<tr>
<th></th>
<th>MAP, mmHg</th>
<th>HR, beats/min</th>
<th>$V_E$, ml/min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Static contraction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$-Chloralose</td>
<td>250 ± 66</td>
<td>88 ± 5</td>
<td>89 ± 6</td>
</tr>
<tr>
<td>Chloral hydrate</td>
<td>304 ± 54</td>
<td>101 ± 5</td>
<td>100 ± 6</td>
</tr>
<tr>
<td>Midcollicular</td>
<td>381 ± 65</td>
<td>103 ± 12</td>
<td>119 ± 24$^*$</td>
</tr>
<tr>
<td>Postcollicular</td>
<td>218 ± 53</td>
<td>88 ± 15</td>
<td>86 ± 15</td>
</tr>
<tr>
<td><strong>Tendon stretch</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$-Chloralose</td>
<td>389 ± 60</td>
<td>91 ± 7</td>
<td>88 ± 8</td>
</tr>
<tr>
<td>Chloral hydrate</td>
<td>468 ± 103</td>
<td>100 ± 13</td>
<td>103 ± 13</td>
</tr>
<tr>
<td>Midcollicular</td>
<td>455 ± 31</td>
<td>107 ± 12</td>
<td>129 ± 16$^*$</td>
</tr>
<tr>
<td>Postcollicular</td>
<td>425 ± 80</td>
<td>82 ± 13</td>
<td>80 ± 12</td>
</tr>
</tbody>
</table>

Values are means ± SE. MAP, mean arterial pressure; HR, heart rate; $V_E$, minute ventilation. The number of preparations is shown in Table 2. Values are obtained from the largest tension in each rat. *P < 0.05 vs. control value.

study of the exercise pressor reflex. Smith et al. (27) speculated that the depressor response obtained from halothane-anesthetized rats could have been caused by halothane-induced changes in neuronal activity in the brain. The varied response pattern in MAP in the anesthetized rats of the present study seems to support this.

An alternative factor making the response to contraction and stretch blood pressure variable could be the difference between static and dynamic contraction. Static contraction did not always evoke pressor response, whereas dynamic contraction always evoked a depressor effect in pentobarbital-anesthetized rats (32). Moreover, it was reported that some cells in the nucleus tractus solitarii (NTS) responded differently to the two types of contraction in rats, implying different processing in the medulla in the different contraction modes (33). This could be a part of the possible factor making the blood pressure response to static contraction varied in anesthetized rats.

The most appropriate decerebrate region for exercise pressor reflex in the present study was not identical with that in previous studies. Smith et al. (27) used precollicular decerebrated rats, and Skinner and Garcia-Rill (26) reported that no spontaneous behavior was observed in precollicular decerebration. On the other hand, spontaneous running behavior in precollicular decerebrated rats was consistently observed during muscle stimulation, as shown in rhythmic muscle tension in category E of Fig. 2. Midcollicular decerebration was most applicable to pressor reflex study, whereas the postcollicular decerebrated rats showed hyperventriculation in the present study. The present study was not intended to identify the site at which spontaneous running originated. However, some possible reasons can be supposed. The mesencephalic locomotor region (MLR) in rats is located ventral to the inferior colliculus (26). It is likely that the region evoking the spontaneous behavior in the present study was the MLR. Furthermore, the substantia nigra (SN), which is located ventral and rostral to the superior colliculi, is responsible for providing an inhibitory input to the MLR in the cat (26). A similar organization is found in the rat (26). Thus pre- and midcollicular decerebration reduced the inhibitory input from the SN, in turn increasing the possibility of spontaneous running as observed in these preparations. On the other hand, as a result of removing the MLR by postcollicular decerebration, the possibility of generating spontaneous running might be decreased in the midcollicularly decerebrate rat and abolished in the postcollicularly decerebrate rat. The balance of inhibitory input from the SN to the MLR and signal from the MLR might partly determine the occurrence of spontaneous running.
The midcollicular decerebration used in the present study was more caudal than that in previous studies (23, 27). This difference of decerebration level could affect the magnitude of the pressor response, as reported in cats (13). The region relevant to blood pressure control has been suggested to be the ventrolateral medulla (VLM; Refs. 3, 13) and the NTS (14, 23). According to the atlas of the rat brain (17), the midcollicular decerebration used in the present study kept these regions intact. Also, reflex responses to orthostatic and chemical stresses are intact in midcollicular decerebrated rats (25). In the present study, the existence of the pressor response to electrical stimulation at >10 times the motor threshold, which directly stimulates group III afferent fibers (21, 33), demonstrates that the preparation had an adequate central neural circuit to manifest a pressor effect.

The exercise pressor reflex occurred in midcollicular decerebrated rats and disappeared in postcollicular decerebrated rats. This means that some structures located between the midcollicular and postcollicular decerebration levels are necessary to fully describe the exercise pressor reflex. However, we should view this with some caution because far caudal structures were suggested to be relevant for evoking the reflex. Iwamoto et al. (13) reported that the neuraxis levels are crucial for the exercise pressor reflex. Also, as mentioned above, the VLM and the NTS are necessary for blood pressure control (3, 14, 23). It is difficult to explain why such rostral structure seems to be necessary for the reflex in the present study. We can only speculate as to the possibility that some structure located between the midcollicular and postcollicular levels receives a neural signal from the medulla, modulates the neural signal, and then plays some role for integrating the exercise pressor reflex in the medulla.

Not only muscle contraction but also stretch elicited the pressor reflex in decerebrate preparations. This clearly indicates the contribution of mechanoreceptors in the muscle to cardiovascular adjustments. The pressor response to tendon stretch, which is attenuated by gadolinium during contraction, demonstrated the contribution of mechanoreceptors in cats (11). The pressor response to tendon stretch was shown in decerebrated rats. The time course of reflex at the onset of stretch was similar to that of contraction. This also resembles the nature of reflex obtained from cat preparations, whereas the topography of reflex is not identical to that in cats.

A greater response to forelimb than to hindlimb stimulation has been reported in cats (10). Also, the forelimb has been successfully used in a rat brain-heart preparation to study the neurophysiology of exercise-related stimuli (23). Therefore, it was antic-
pated that forelimb stimulation in rats would elicit a greater response and be a more useful preparation than stimulation of the hindlimb. Unfortunately, how-

ever, forelimb stimulation was not appropriate because it frequently evoked spontaneous behavior even in midcollicular decerebrated rats. The differences be-

tween the previous study (23) and the present study were the ages of rats and surgery, but the determining factor is unclear.

Anesthetized rats. Anesthesia has been reported to suppress MAP, HR and $\dot{V}_E$ responses to muscle con-

traction. Knowledge of these effects of anesthesia on the MAP, HR and $\dot{V}_E$ responses to muscle contraction may be important for correctly interpreting responses in the presence of anesthetic agents, because rats are often used to characterize cardiovascular changes and neuronal pathways.

Some studies have reported a consistent pressor re-

flex to static contraction evoked by sciatic nerve stim-

ulation in anesthetized rats (2, 19). In the present study, the same anesthetic agents were used but no consistent pressor reflex was obtained. The difference between the previous (2, 19) and present studies was the amount of chloral hydrate used. In the present study, 150 mg/kg of chloral hydrate and 25 mg/kg of pentobarbital sodium were given intraperitoneally at the start of each surgery, whereas in the previous studies (2, 19) 75 mg/kg of chloral hydrate and 25 mg/kg of pentobarbital sodium were given intraperito-

neally at the start of each surgery. The total amount of chloral hydrate given before starting the experimental trials ranged from 275 to 350 mg/kg in the present study, whereas this total amount was not reported in the previous studies (2, 19). In the present study, the anesthesia was not sufficiently maintained at the same level as that used in the previous reports. The appro-

priate amount, when given as a single dose, of chloral hydrate and pentobarbital sodium is 300–400 and 10–45 mg/kg, respectively (5). The anesthetic dose could affect the response to muscle contraction as well as that reported in the response to nociception (6). Fur-

ther studies are needed to clarify the anesthetic dose appropriate for studying the nature of the exercise pressor response.

Noxious stimulation elicits group III and IV afferent fi-

ring. Similar to muscle contraction, the response to noxious stimulation is not consistent among precollicu-

lar decerebrated, and pentobarbital- and halothane-

anesthetized rats (6, 8, 20). On the other hand, it was reported that electrical stimuli of varied frequency and intensity applied to the sciatic, peroneal, sural, and saphenous nerves evoked pressor responses, in con-

trast to a depressor response evoked by stimulation of the tibial and muscular branch of the femoral nerves in urethane-anesthetized rats (28). The tibial nerve does not innervate skin. Thus the latter study (28) sug-

gested that the electrical stimulation of nerves exclu-

sively innervating muscles consistently evoked depres-

sor responses, whereas the stimulation of nerves sup-

plying skin evoked pressor responses in urethane-

anesthetized rats. Together with the present study, it is possible that the factors masking the pressor reflex to contraction and stretch were due not only to anes-

thesia but also to different neural processing in cuta-

neous and muscle nerves.

There is an effect of species as well as anesthesia on the responses to contraction. It was repeatedly re-

ported that decerebrated cat preparations show a pressor reflex to both static and repetitive muscle contrac-

tions (10, 11, 13, 36). $\alpha$-Chloralose- and urethane-anes-

ethetized rabbits showed a depressor response to repetitive contractions (18). $\alpha$-Chloralose- and ure-

thane-anesthetized mice showed a pressor reflex to static contractions (15). The magnitude of the observed pressor response was similar to that in the present and previous reports in decerebrated rats. Of importance, humans show a pressor response to static exercise as well as to electrically induced muscular contraction (12), so it is essential to use a species eliciting a pressor response to exercise-related stimuli. Therefore, rats or other rodents are applicable to study of cardiorespira-

tory responses to exercise.

In the present study, the effect of anesthesia and decerebration on the exercise pressor reflex in rats was investigated. The midcollicular decerebrated rats showed consistent pressor reflexes both to hindlimb muscle con-

traction and stretch, suggesting that metabo- and mech-

anosensitive muscle receptors evoked these effects. De-

cerebration was shown to be an effective method to reveal the exercise pressor reflex, whereas the region appropriate for studying the reflex is slightly contro-

versial, i.e., pre- or midcollicular decerebration (23, 27). On the other hand, anesthetized rats showed no con-

sistent exercise pressor reflex. Use of the decerebration model will provide further insight into neural regula-

tion of the cardiovascular and respiratory systems origin-

ating from exercising.

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cation, Science, Sports, and Culture of Japan.

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