The Effects of Infrasound on Pituitary Adrenocortical Response and Gastric Microcirculation in Rats

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Abstract

To clarify the effects of infrasound on the body, rats were exposed acutely to infrasound. Responses of the pituitary adrenocortical system of the rats to infrasound were evaluated with their frequency characteristics according to changes of the plasma ACTH and corticosterone (corl) concentrations. The gastric mucosal blood flow of rats was determined by the inhaled hydrogen gas clearance method, and changes in the microcirculation of the gastric mucosa by infrasound were evaluated.

1. The frequency characteristics of the responses of the rat pituitary adrenocortical system were parallel to, and about 30 dB above, the threshold of sensation in the humans, and corresponded to about 80 phon on the equal-loudness curves.

2. The gastric mucosal blood flow of the rats exposed to 16 Hz infrasound at 120 dB for 20 minutes was significantly reduced by 19.1% (p<0.01) 10 minutes after the beginning of the exposure as compared with the pre-exposure level. The percent changes of the blood flow were significantly smaller (p<0.01) in the exposure group 10 minutes after the beginning, and 10 minutes after the end of the exposure than in the control group.

From the results above, it seems probable that exposure to infrasound might influence the endocrine system and even autonomic nervous system.

1. Introduction

There have been a large number of reports on the effects of noise on the human body from the viewpoints of human ecology. Recently, further advancements in the industrialization of society have aroused great interest in new environmental problems on the effects of low frequency noise, including infrasound.

Although, in acoustical physics, infrasound, which is an aerodynamic fluctuation, may be understood as an extension of the effects of noise in the audible frequency range, its effects on the body cannot be pertinently evaluated by the methods applied to audible noises. One of the reasons for this difficulty in evaluation of the effects of infrasound is multiplicity of the sensation aroused by infrasound; in addition to tonal response, it is felt as vibration and pressure, characteristic of infrasound consisting of very low frequencies (Refs. 1,2).

Subjective evaluations are generally of primary importance in assessing the effects of environmental factors received as sensory stimuli, but a subjective scale must be understood in relation to an appropriate objective reference.

Incidentally, as regards the effects of infrasound on the body, epidemiological investigations of the victims of infrasonic noise have suggested that they primarily cause non-specific stress reactions via disturbances of the autonomic nervous and endocrine systems (Ref. 3). Some organs may undergo latent changes even before the appearance of subjective symptoms or physiological changes.

In this study, responses of the pituitary adrenocortical system in animals acutely exposed to infrasound were studied with their frequency characteristics, and possible changes in the peripheral hemodynamics of the stomach. This is considered to be susceptible to influences from the autonomic nervous and endocrine systems, and particularly vulnerable to stress.
2. Methods

2.1 Experiment I

This study was carried out on 158 mature male Wistar rats (36 controls and 122 exposed to infrasound) weighing about 300 gm each.

For one week before exposure to infrasound, two animals each were housed in a cage in a sound-shielded room with a background noise of 40 dB(A) or below and a temperature of 24 ±2°C with alternating light (7:00 – 21:00) and dark (21:00 – 7:00) periods. Food (solid stock food, MF) and water (tap water) were given ad libitum.

On the day of exposure to infrasound, the animals were transferred from the sound-shielded room to the infrasound chamber at 09:00, and were acclimatised to the chamber for about 4 hours until the exposure. Four to six animals were simultaneously exposed to infrasound at 13:00.

Figure 1. Set-up for exposure to infrasound; the effective air capacity of the chamber is 0.52m³ (59.5cm x 99.8cm x 87.0cm).

Figure 2. The frequency characteristics of the chamber by FFT spectrum analyser (SA-70 RION).

Figure 1 shows the apparatus for exposure to infrasound. The chamber has a floor area of 0.59 m² and an effective air capacity of 0.52 m³. To generate infrasound the output of the function generator (SD 405, Sistron Donner) was amplified by the power...
amplifier (SE-A5MK2, National) and fed to two 38 cm loudspeakers (EAS-38L100, Technics) attached to the chamber. The sound pressure level in the chamber was monitored directly with a 1-inch condenser microphone (B. & K 4144) connected to a sound level meter (B. & K. 2606) placed outside the chamber.

Table 1: Sound Stimuli Used in the Experiment

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Sound Pressure Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8Hz</td>
<td>80 100 120 130</td>
</tr>
<tr>
<td>16Hz</td>
<td>80 100 120</td>
</tr>
<tr>
<td>32Hz</td>
<td>70 80 100 120</td>
</tr>
</tbody>
</table>

The sound conditions were pure tones of 8, 16 and 32 Hz at sound pressure levels ranging from 70 dB to 130 dB. The exposure time was 15 minutes in all cases (Table I). The levels of harmonic distortion produced by each fundamental in the chamber were within the range of the background noise and could be ignored (Figure 2).

Responses of the pituitary adreno-cortical system of the rats to infrasound were evaluated according to changes of the concentration of ACTH and corticosterone (corti) in plasma.

Right after exposure, blood samples were collected by cardiocentesis using a plastic syringe containing EDTA-2Na under anesthesia by intraperitoneal administration of 400-500 mg/kg sodium pentobarbital with ether induction. The collected blood was immediately transferred to plastic tubes, centrifuged at 4°C, and the plasma obtained was kept frozen below −20°C before being quantified.

The controls were treated in the same way as the exposure group was, except that they were not exposed to infrasound.

The concentration of ACTH in plasma was measured by radio-immunoassay kit (ACTH-PR Kit, CIS) based on the method outlined in Figure 3a (Ref. 4). The concentration of corti. in plasma was measured by the fluorometric technique described by Zenker and Bernstein (Figure 3b, Ref. 5).

![Diagram](image_url)

Figure 3. (a) Assay procedure of plasma ACTH, (b) Measuring procedure of plasma corticosterone.
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2.2 Experiment II

This study was carried out on 29 mature male Wistar rats weighing about 300 gm each. The animals were intraperitoneally anaesthetized with 50 mg/kg sodium pentobarbital one week before the exposure to infrasound, exposing their stomachs by median laparotomy.

An indicator electrode shown in Figure 4 was inserted and fixed from the serous side of the glandular portion of the stomach with poor vasculization. A reference electrode was embedded with an indicator electrode lead subcutaneously in the head. The indicator electrode was made of a polyurethane-covered platinum wire 100 μm in diameter coated with a silicone tube. The 1mm sensor portion immediately below the tip was exposed and coated with platinum black, and a needle for puncture was attached to the tip (Figure 4).

![Diagram](image)

Figure 4. Schematic diagram of electrode; the sensor portion is coated with platinum black and its diameter is 100μm.

The animals were maintained for one week as in Experiment I until they were exposed to infrasound. On the day of the experiment, the animals were allowed about 4 hours to eliminate the excitement factor as in Experiment I, then they were exposed to 16 Hz infrasound at 120 dB intensity for 20 minutes after 13:00.

The gastric mucosal blood flow of the animal was measured with a hydrogen clearance tissue flowmeter (UH-meter MHG-D1, Unique Medical) consisting mainly of the head for variable potential loading and detection of a diffusion current, an amplifier, and a computer (Figure 5).

To perform the experiment under ordinary physiological conditions without anaesthesia and restraint, the animal was placed in a gas-mixed chamber shown in Figure 6. The animal was allowed to inhale hydrogen gas mixed with sufficient oxygen for 2 minutes. The concentration of hydrogen was adjusted to about 10 vol. per cent, because of little influence on the systemic blood circulation and the arterial gas partial pressure. The regional blood flow of the gastric mucosa was calculated according to Zierler’s stochastic analysis (Ref. 6).

![Diagram](image)

Figure 5. Block diagram of the hydrogen clearance tissue flowmeter (UH-meter MHG-D1, Unique Medical). T.C.: time constant, APP.V.: applied voltage, OP. time; operation time, S; sensor, R; reference.

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Figure 6. Schema of inhalation chamber: it is made of vinylchloride and is 0.5mm in thickness. The effective air capacity is 7.65x10cm$^3$ (17cmx25cmx18cm)

Table II: Plasma ACTH and Corticosterone (corti.) Levels of the Control Group

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>Mean S.E.</th>
<th>URL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTH(pg/ml)</td>
<td>36</td>
<td>275.3±16.4</td>
<td>478.3</td>
</tr>
<tr>
<td>corti. (µg/dl)</td>
<td>34</td>
<td>12.8±1.1</td>
<td>25.0</td>
</tr>
</tbody>
</table>

- URL: upper rejection limit

3. Results

3.1 Experiment I

Table II shows the average concentration and standard error (SE) of ACTH and corti. in plasma, and the upper rejection limit in the control group.

Since this study was performed during a short time period at a fixed time of the day, variation due to circadian rhythm can be ignored. As for seasonal changes (Ref. 7), there was also no significant difference in the concentration of ACTH or corti. in plasma throughout the year. Figure 7 shows the average concentration and SE of ACTH and corti. in plasma in the exposure group at each frequency and sound pressure level. Significant differences ($p<0.01$) as compared with the control group were observed in the concentration of ACTH in plasma at 8 Hz-130 dB, 16 Hz-120 dB, and 32 Hz-100 dB, and in the concentration of corti. in plasma at 8 Hz-130 dB, 16 Hz-120 dB, and 32 Hz-100 dB and 120 dB. An intensity response relationship was nearly observed at each frequency with the exception of a decrease noted at 32 Hz-120 dB.

The upper rejection limits of the concentration of ACTH and corti. in plasma were 478.3 pg/ml and 25.0 mg/dl, respectively, in the control group (Table II). Table III shows the number of animals of the exposure group that showed abnormal values exceeding the upper rejection limits of the control group at each sound condition. The percentage of animals showing abnormal values increased with the increase in the sound pressure level at each frequency except for a slight decrease at 32 Hz-120 dB.
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![Graphs showing effects of infrasound on ACTH and corticosterone](image)

Figure 7. Effect of infrasound on changes in contents of ACTH and corticosterone in rat's plasma. (Data are expressed as the mean ± S.E.).

Table III: Numbers of Animals of the Exposure Group That Showed Abnormal Values Exceeding the Upper Rejection Limits of the Control Group at Each Sound Condition. (The number of the denominator is the total number of animals in each sound condition)

(a) ACTH

<table>
<thead>
<tr>
<th>SPL</th>
<th>8Hz</th>
<th>16Hz</th>
<th>32Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>70dB</td>
<td>0/8</td>
<td>0/12</td>
<td>0/9</td>
</tr>
<tr>
<td>80dB</td>
<td>0/12</td>
<td>0/12</td>
<td>0/10</td>
</tr>
<tr>
<td>100dB</td>
<td>2/14</td>
<td>1/9</td>
<td>3/12</td>
</tr>
<tr>
<td>120dB</td>
<td>6/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130dB</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) corticosterone

<table>
<thead>
<tr>
<th>SPL</th>
<th>8Hz</th>
<th>16Hz</th>
<th>32Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>70dB</td>
<td>1/7</td>
<td>0/11</td>
<td>1/6</td>
</tr>
<tr>
<td>80dB</td>
<td>0/12</td>
<td>2/9</td>
<td>0/10</td>
</tr>
<tr>
<td>100dB</td>
<td>4/13</td>
<td>5/10</td>
<td>5/11</td>
</tr>
<tr>
<td>120dB</td>
<td>8/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130dB</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SPL: sound pressure level

Figure 8 summarizes frequency characteristics of the responses of the pituitary adrenocortical system to acute short-time exposure to infrasound of various frequencies and sound pressure levels. Significant differences as compared with the control group were observed at the sound pressure levels of infrasound between 80 dB and 100 dB at 32 Hz, and the sound pressure levels were likely to go up at lower frequencies.

3.2 Experiment II

During experiment II, the animals behavior was observed. Before the exposure to
infrasound, the animals acclimatised themselves to the environment and kept quiet.  

Immediately after the exposure to infrasound, some of them moved slightly such as raising their heads, squatting or shifting their position.  

It is understood that the animal appears to sense the infrasound through some receptors.  

Animals showing marked instabilities in the clearance curve or deviations in the baseline, and those in which the sensor clearly missed the mucosal layer, were excluded from measurement of the gastric mucosal blood flow. Figures 9 and 10 show an instance of the clearance curve and a histological profile of the gastric wall of a rat in the control group.

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**Figure 8.** The frequency characteristics of the pituitary andrenocortical response. *---*: Significant increase to the control group. Under the sound condition in the part of the oblique lines (////), infrasound as a stressor will affect the pituitary andrenocortical system in rats.

**Figure 9.** An instance of the clearance curve obtained from the gastric mucosa of a rat in the control group. $F$: bloodflow calculated according to Zierler's stochastic analysis (Height-Area Method); $\lambda$: tissue/blood partition coefficient.
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Figure 10. A microscopic photograph of the gastric wall of a rat in the control group stained by H.E. (Hemotoxylin-Eosine)

Table IV: Reproducibility of the Gastric Mucosal Blood Flow (ml/min/100gm) Calculated by Inhalation Method

<table>
<thead>
<tr>
<th>No.</th>
<th>Blood Flow</th>
<th>d</th>
<th>Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>59.2</td>
<td>53.6</td>
<td>5.6</td>
</tr>
<tr>
<td>2</td>
<td>55.4</td>
<td>50.7</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>45.2</td>
<td>58.7</td>
<td>13.5</td>
</tr>
<tr>
<td>4</td>
<td>75.6</td>
<td>82.1</td>
<td>6.5</td>
</tr>
<tr>
<td>5</td>
<td>65.4</td>
<td>62.7</td>
<td>2.7</td>
</tr>
<tr>
<td>6</td>
<td>42.6</td>
<td>46.7</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>61.7</td>
<td>62.0</td>
<td>0.3</td>
</tr>
<tr>
<td>8</td>
<td>58.6</td>
<td>62.7</td>
<td>4.1</td>
</tr>
<tr>
<td>9</td>
<td>74.5</td>
<td>69.8</td>
<td>4.7</td>
</tr>
</tbody>
</table>

4.4±3.5

Figure 11. Changes of the gastric mucosal blood flow
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Flowmetry was performed twice at the same site of the gastric mucosa in 9 controls to examine the reproducibility of the measurement (Table IV). Variation of the values was 4.4 ± 3.5% with a “t” value of 0.86.

Figure 11 shows serial changes in the gastric mucosal blood flow of the control and the exposure groups expressed in terms of percent changes as compared with the pre-exposure values.

The pre-exposure gastric mucosal blood flow was 61.4 ± 10.6 ml/min/100 gm in the control group and showed no marked changes during the 40-minute experimentation. In the exposure group, the gastric mucosal blood flow showed a 19.1% reduction (p < 0.01) as compared with the pre-exposure level 10 minutes after the beginning of the exposure to infrasound. Then, the blood flow tended to recover 20 minutes after the beginning of the exposure, slightly reduced again after the end of the exposure, and gradually recovered thereafter. The percent changes of the blood flow were significantly smaller (p < 0.01) in the exposure group 10 minutes after the beginning, and 10 minutes after the end, of the exposure than in the control group.

4. Discussion

Short-time exposure to high level infrasound affects the middle ear, vestibular system, and respiratory system together with sensations of vibration over the whole body and of pressure in the chest and abdomen (Refs. 8-13).

Perforation of the tympanic membrane and otalgia are more direct effects of the infrasound. Slarve et al. (Ref. 8) observed that at 172 dB, exposure of 1 Hz for 60 minutes, 4 Hz for 15 minutes, and 8 Hz for 7.5 minutes all produced perforations of the tympanic membrane in chinchillas. Lim et al. (Ref. 9) obtained similar results using rats. Parker et al. (Ref. 10) noted nystagmus in guinea pigs exposed to infrasound at 150 dB or above, and Johnson (Ref. 11) observed progressive reduction in the respiratory rate in the anaesthetized dog at 166 dB or above, terminating in respiratory arrest at 172 dB at frequencies of 1 Hz or below.

The results of these studies were obtained at very intense infrasound seldom encountered in practice. Studies on the effects of noise in the audible frequency range had similar tendencies, because the sound pressure levels of the noise must be very high if direct effects of the noise are to be evaluated according to physiological indices.

The primary effects of noise or vibration on the body are those received through sensory organs, which are known to exert profound mental and psychological effects. This is true of infrasound. Frequency characteristics of its effects on the body have been evaluated according to various parameters such as the threshold of sensation (Refs. 14, 15), loudness (Refs. 16, 17), and annoyance (Ref. 18). The subjectivity of these parameters suggests the importance of mental and psychological effects of infrasound, which eventually leads to physiological and objective consequences. Infrasound causes non-specific physical symptoms, so called stress reactions, due to disorders of the autonomic nervous and endocrine systems secondary to mental and psychological changes.

In this study, the effects of infrasound as a stressor were examined according to responses of the pituitary adrenocortical system of rats.

There is an intensity-response relationship between the sound pressure level of the noise of the audible range and the response of the pituitary adrenocortical system of rats acutely exposed to the noise. Osaki et al. (Ref. 19) subjected rats to white noise of 60-100 dB(A) for 30 minutes, and observed that the mean plasma corti. concentration significantly increased above 60 dB(A) but stabilized at 80 dB(A) or above, and that its standard deviation became significantly greater than that of the control at 70 dB(A) but decreased at higher sound pressure levels to a value significantly smaller than that of the control at 100 dB(A). Matsui et al. (Ref. 20) measured the total cholesterol and 11-OHCS concentrations in the adrenal glands in rats exposed to the wide band noise at the intensities of 60, 80, and 100 dB, and reported an intensity-response relationship between the extent of temporary hyperadrenalism early in the exposure period and the sound pressure level.

Sato et al. (Ref. 21) subjected rats to continuous or intermittent exposure to the wide band noise at 60, 80, and 100 dB, and examined changes in the serum and adrenal 11-OHCS levels. The serum 11-OHCS levels increased early in the exposure period under all conditions, but the adrenal 11-OHCS levels showed no significant increases in the animals exposed to intermittent noise occurring in 2-second cycles as compared with the control group.
In Maca's study using dogs (Ref. 22), the plasma 17-OHCS level, which increased at 120 dB (white noise), decreased at 130 dB (white noise). A study of Osaki et al. (Ref. 19) using rats also suggested the presence of the upper limit of the intensity-response relationship between the noise level and the adrenocortical function.

In this study, the plasma ACTH concentration was elevated with the increase in the sound pressure level at each frequency, with the difference, as compared with the control, being significant at 8 Hz-130 dB, 16 Hz-120 dB, and 32 Hz-100 dB. However, the plasma ACTH concentration was reduced at 32 Hz-120 dB, suggesting the presence of a peak response level as in audible noise. The plasma corti. concentration showed similar changes.

From these results, the frequency characteristics of the responses of the pituitary adrenocortical system in rats to acute short-time exposure to infrasound, was made clear, namely, under the condition of frequencies and sound pressure levels in the part of the oblique lines showed in Figure 8, infrasound as a stressor will affect the pituitary adrenocortical system in rats.

![Figure 12. Comparison between equal loudness curves (-----), threshold of sensation (-----), and the present study (-----)](image)

Figure 12. Comparison between equal loudness curves (-----), threshold of sensation (-----), and the present study (-----)

In Figure 12, the frequency characteristics of the response of the pituitary adrenocortical system in rats is superimposed over the threshold of sensation (Ref. 14) in the humans and the equal loudness curves (Ref. 17). This frequency characteristic which showed significant differences as compared with those of the control is nearly parallel to the threshold of sensation in the humans and to the equal loudness curves; it was about 30 dB above the threshold of sensation in the humans, and corresponded to about 80 phon on the human equal loudness curves.

In general, the response of the pituitary adrenocortical system to sound stimulation varies with conditions of exposure such as the acoustic characteristics (frequency composition, sound pressure level) of the noise, exposure duration, and the manner of exposure. However, factors of the host exposed to the noise are considered to have even greater importance, especially in the humans. As the study of Sato et al. (Ref. 21), in which responses of the adrenocortical system were examined in rats and humans subjected to noise of the same acoustic characteristics and intensity, suggested that our present findings in animals could not be directly applied to the response of humans exposed to infrasound.
Since Burton-Opitz (Ref. 23) developed the direct venous perfusion method in 1910, gastric blood flow has been evaluated by various methods (Ref. 24). By the clearance method, the blood flow is determined from the rate at which the indicator administered to the target organ is washed away by the blood flow of the measurement site.

Flowmetry by hydrogen gas clearance has been applied to various organs since its introduction by Auckland (Ref. 25), and is highly reliable. The blood flow is calculated conventionally by $T_v$ method based on the clearance theory of Key & Schmidt (Ref. 26) derived from Fick’s principle. This method, however, has disadvantages that the graphic process for determination of the half-time is associated with some variation, considerable amount of time is needed for calculation, and the theory is valid only under certain preconditions.

On the other hand, by the method used in this study, the tissue hydrogen clearance curve is calculated by the Height-Area method based on the stochastic analysis of Zierler (Ref. 6), in which the clearance curve is regarded as representing the frequency distribution of the transit times, and the mean transit time is calculated from the curve. This eliminates the necessity of graphs, and the values are obtained readily with a built-in computer in the apparatus. Nevertheless, a few precautions must be fulfilled for Zierler’s theory to be valid: 1) the flow is constant and the arterial and venous flows are equal; 2) there is no change in the frequency distribution of the tissue transit time of the radioisotopes, i.e. the tissue distribution of the blood flow is constant; and 3) each radioisotope molecule that passes through the tissue always corresponds to the blood flow (Refs. 27, 28). Although this method is also incapable of accurate determination of the true blood flow, it allows approximate determination of the blood flow in the absolute value.

As for the effects of noise on digestive tracts, decreases in salivary and gastric juice secretion and reduction in the gastric and intestinal movements have been demonstrated in animals and humans. These changes are due to a shift of the autonomic nervous system, which regulates visceral activities, to sympathetic dominance as well as increase in hormones secreted by the pituitary adrenocortic system. Since these changes are elicited by not only noise but also cold, pain, injury, and mental strain, they are considered to be non-specific and indirect responses in consequence of mental and psychological stress (Refs. 29, 30).

Concerning infrasound, Landström (Ref. 31) exposed 20 subjects to infrasound of 16 Hz-125 dB for 60 minutes and observed an increase in gastric acid secretion in 10 subjects during the exposure.

On the other hand, there have been few studies on the effects of infrasound on the blood flow of the digestive organs. Namiki et al. (Ref. 32) measured hepatic blood flow by the hydrogen gas clearance method in restrained rats under audible noise stress, and noted a slight reduction in the blood flow as compared with the controls, and suggested that it was caused by constriction of portal vein and sinusoid with adrenal secretion. However, this finding may not reflect the effect of noise since restraint itself is a strong stress.

The evaluation of the blood flow was made under the normal conditions without anaesthesia and restraint by using a gas-mixed chamber set out in Figure 6 and a chronically implanted platinum microelectrode in the stomach of a rat. And, it has also the advantage of being able to confirm exactly its position in the gastric wall by histological reasearch.

When the animals were exposed to 16 Hz infra sound at 120 dB for 20 minutes, the blood flow was significantly reduced as compared with the pre-exposure level and the controls 10 minutes after the beginning of exposure. It nearly returned to the initial level just before the end of the exposure, but decreased temporarily again 10 minutes after the end of the exposure and recovered gradually thereafter. The blood flow was clearly affected by the imposition and removal of infrasound.

With regard to factors that produce changes in the gastric mucosal blood flow under stress, Matsuo (Ref. 33) observed contraction of regional arterioles and stagnation of capillary blood flow by stimulation of the hypothalamus, a sympathetic center, and abdominal splanchic nerves, but disappearance of these changes by blocking of abdominal splanchnic nerves, and emphasized the importance of the role of the sympathetic nervous system in microcirculation of the gastric mucosa. Guth et al. (Ref. 34) noted a marked reduction in the gastric mucosal blood flow by administering norepinephrine, a neurotransmitter of the adrenergic nerves, directly into an artery of the stomach.

Okada et al. (Ref. 35), on the other hand, observed a significant increase in the
blood flow in hypophysectomized rats as compared with the intact controls in a study of stress-induced gastric ulcer. The experiment also demonstrates that infrasound of 16 Hz-120 dB acts as a stressor on the pituitary adrenocortical system and increases secretion of ACTH and corti.

From these results, it is understood that exposure to 16 Hz infrasound at 120 dB appears to induce sympathetic-dominant responses early in the exposure period due to stimulation of the sympathetic nervous system by the hypophysis directly or indirectly via the adrenal glands.

Although this study makes it clear that infrasound induces changes in the peripheral gastric mucosal blood flow, further studies are needed for elucidation of the causes or the mechanism of these changes, in which complex factors are considered to be involved.

5. Conclusion

To clarify the effects of infrasound on the body, rats were exposed acutely to infrasound.

Responses of the pituitary adrenocortical system of the rats to infrasound were evaluated with their frequency characteristics according to changes of the plasma ACTH and corti. concentrations.

The gastric mucosal blood flow of rats was determined by the inhaled hydrogen gas clearance method, and changes in the micro-circulation of the gastric mucosa by infrasound were evaluated. The results were as follows:

1. The plasma ACTH concentration increased significantly in rats exposed to infrasound of 8 Hz-130 dB, 16 Hz-120 dB, and 32 Hz-100 dB for 15 minutes as compared with the controls.

2. The plasma corti. concentration increased significantly in rats exposed to infrasound of 8 Hz-130 dB, 16 Hz-120 dB, and 32 Hz-100 dB and 120 dB for 15 minutes as compared with the controls.

3. The frequency characteristics of the responses of the rat pituitary adrenocortical system were parallel to, and about 30 dB above, the threshold of sensation in the humans, and corresponded to about 80 phon on the equal-loudness curves.

4. The pre-exposure gastric mucosal blood flow of the rats was 61.4± 10.6 ml/min/100gm in the control group and showed no major changes during the 40-minute experimentation.

5. The gastric mucosal blood flow of the rats exposed to 16 Hz infrasound at 120 dB for 20 minutes was significantly reduced by 19.1% (p<0.01) 10 minutes after the beginning of the exposure as compared with the pre-exposure level.

6. The percent changes of the blood flow were significantly smaller (p<0.01) in the exposure group 10 minutes after the beginning, and 10 minutes after the end, of the exposure than in the control group.

From the results above, it seems probable that exposure to infrasound might influence the endocrine system and even autonomic nervous system.

Acknowledgement

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