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The telemetric monitoring of heart rate during copulatory behavior in the male rat

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Introduction

Activation of the hypothalamus, in particular the medial preoptic area (MPOA), and excitation of the related autonomic nerves are thought to be involved in the expression of the sexual response cycle. Blumberg et al. (1987) reported that tissue temperature of the MPOA in male rats was high prior to ejaculation, and then rapidly decreased. Neurons in the sympathetic nervous system that regulate blood circulation are mainly found in the spinal cord, medulla oblongata and hypothalamus. These tissues contain centers of important regulatory functions, such as the MPOA which regulates body temperature and male sexual behaviors, and the ventromedial hypothalamus (VMH) which regulates appetite, metabolism and running. Moreover, the neurons in the sympathetic nervous system that regulate blood circulation are directly and indirectly affected by the MPOA and VMH. Several studies have investigated the heart rate of large animals such as cattle and horses during ejaculation *(Too et al. 1973)*, but relatively few provide detailed analyses of changes in the heart rate of small animals such as rats during a series of copulatory behaviors.

Therefore, the present study is a detailed investigation in male rats of copulation-induced changes of heart rate and an analysis of the involvement of autonomic nerve function of a small telemetric transmitter.

Materials and Methods

Animals

Specific-pathogen-free Iar: Wistar-Imamichi rats of both sexes were obtained from the Imamichi Institute for Animal Reproduction (Ibaraki, Japan) at 4 weeks of age. These animals were seronegative for *Mycoplasma pulmonis*, *Bacillus pilifomis*, *Bordetella bronchiseptica*, *Streptococuss pneumoniae*, and Sendai virus. Rats were housed in suspended wire-mesh cages (width x depth x height, 310 x 440 x 230 mm) in groups of 4 animals / sex / cage, kept in an animal room with controlled temperature (24 ± 2 ^{0} C) and humidity (55 ± 10%). A 14:10-h light:dark cycle, with lights on at 05:00, prevailed. Food (Oriental MF, Oriental Yeast Co., Ltd., Tokyo, Japan) and tap water were always available.

Surgery

On reaching the age of 10 to 12 weeks, 12 males (310 to 340 g) were subjected to surgery. A small telemetric transmitter (TA10E-F2, Data Science Co., Ltd., Minnesota, USA) for ECG was implanted into each animal, as described by Ishii et al. (1996). Briefly, the transmitter was implanted in the dorsal area of the neck subcutaneously under pentobarbital sodium anaesthesia (40 mg/kg, i.p.) and the paired wire electrodes were placed under the skin of the thorax (chest bipolar ECG lead). Animals were used 4-7 days after surgery. AM signals transmitted from the telemetric transmitter were amplified as analogue ECG waveforms by a receiver and then analyzed by an ECG processor (Softron, Tokyo, Japan). The heart rate of rats was measured every minute by the data editing function of the ECG processor.

Copulation

Copulatory behavior-induced changes in heart rates were measured for one hour starting at 19:00 hr under a red light. One male was placed in an observation cage (310 x 410 x 270 mm) and a sexually receptive female rat aged 8 to 9 weeks, whose vaginal smears had proestrous features after consecutive repetitions of 2 cycles of the 4-day estrous cycle, was placed in the same cage five min later. To identify ejaculation, the male's 22-kHz vocalization was monitored, using two Mini Bat-Detectors (QMC, Ltd., London, England) tuned to a range of 20 to 30 kHz (Blumberg & Moltz 1987, 1988).

Exercise

In addition, to compare changes in heart rates caused by copulation and exercise, rats were placed in a cage equipped with an exercise wheel (radius x width, 200 x 110 mm) at 19:00 hr for approximately 10 min (6 rpm, 7.7 m). Heart rate was measured every minute for ten minutes. Each rat was made to exercise three times.

Statistical analysis

All values are expressed as mean ±SEM for each category. Statistical analysis based on Student's t-test was performed for comparisons and $p<0.05$ was taken as a significant difference.

Results and Discussion

Figure 1 is the record of heart rate changes of a single male both prior to and following five ejaculations. It is evident that the heart rate began to increase within one minute after the receptive female was introduced. This increase continued until the first ejaculation, whereupon there was a rapid fall in heart rate. After the decrease of heart rate stopped, the first intromission of the next series occurred. This pattern of heart rate increasing to the minute of ejaculation and heart rate decreasing following ejaculation was evident throughout the copulatory series.

Figure 2 shows, for all animals across at least four ejaculations for each animal, mean values in heart rate before and after each ejaculatory series. The mean heart rate of male rats at rest (five minutes before the introduction of a receptive female) was 370 ± 6 bpm, but it rapidly increased to 482 ± 33 bpm introduction of an receptive female to the cage. Heart rate remained at this level during the first intromission. Heart rate subsequently to 519 ± 13 bpm during ejaculation. Following ejaculation, heart rate rapidly decreased and within a couple of minutes had returned to a level comparable to that at rest heart rate. The mean heart rate for the second measurement (one minute after ejaculation) was 397 ± 11 bpm. Heart rate fluctuated slightly during sexually refractory period between 409 and 432 bpm. Changes in heart rate following ejaculation could be replicated. On the other hand, upon introduction of a non-receptive female rat, heart rate increased transiently (437 ± 41 bpm), but remained at the pre-introduction level for the duration of observation (unpublished data).

To determine if the heart rate profile just described reflects merely the heightened activity of copulation and then the relative quiescence that follows ejaculation, we run our animals on a motor-driven wheel at speed of 7.7 m / min. Figure 3 shows mean changes in heart rate relative to heart rate at the end of ejaculation or exercise. The mean heart rate following ten minutes of forced exercise was 490 ± 15 bpm, which was slightly lower than that during ejaculation. Following forced exercise, heart rate decreased gradually, returning to the heart at rest level after more than three minutes. However, following ejaculation, it returned to the normal level after approximately one minute.

The results of the present study clarify that the heart rate of male rats begins to increase before copulating with a receptive female rat and that heart rate peaks during ejaculation. Heart rate during ejaculation is comparable to that induced by maximum exercise (542 - 554 bpm) (*Bolter & Atkinson 1988).* Following vigorous exercise, heart rate does not decrease rapidly, but remains high for a period of time before decreasing. This is a physiologically important event to compensate for a loss of enzymes in the body and prevent an elevation in the partial pressure of carbon dioxide in arterial blood. Furthermore, the results of the present study show that the rate of heart rate recovery was significantly slower following exercise when compared with recovery rate following ejaculation. These findings suggest that

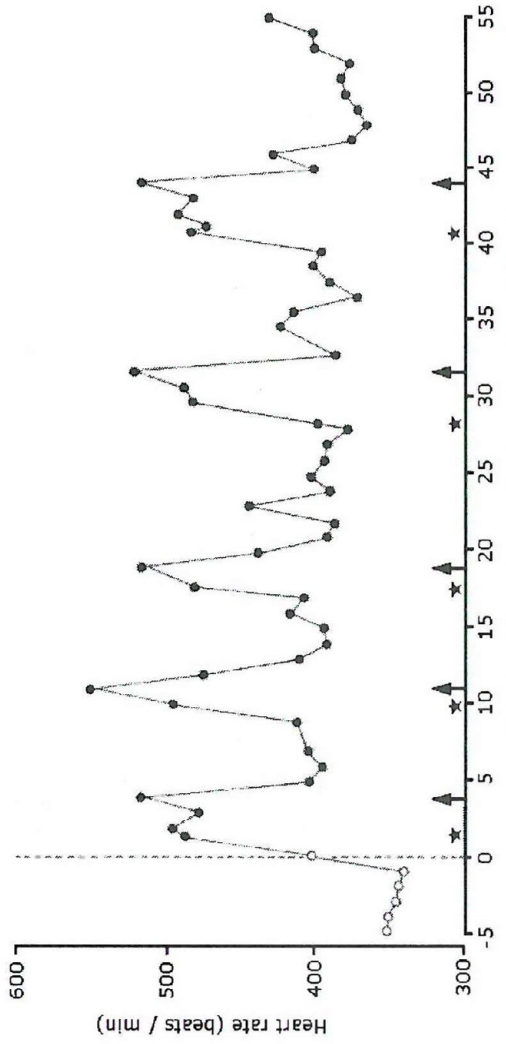

Fig. 1 Heart rate during copulation in a single male (#4). Arrows indicate time of ejaculation and asterisks indicate time of first intromission of each ejaculatory series.

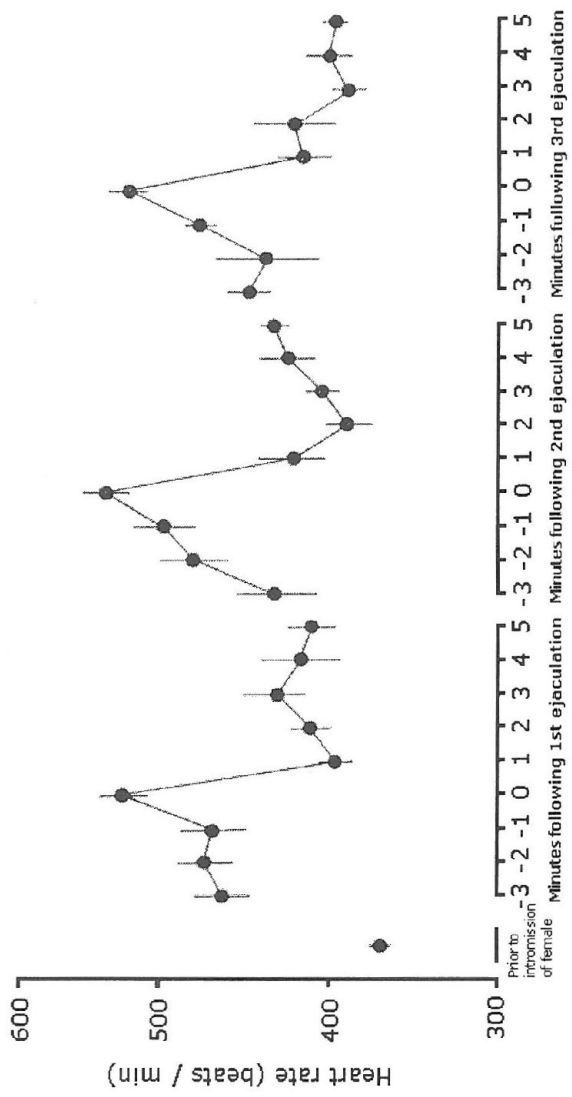

Fig. 2 Changes of heart rate prior to and following ejaculation in male rats (n=6). Each point represents a mean ± SE.

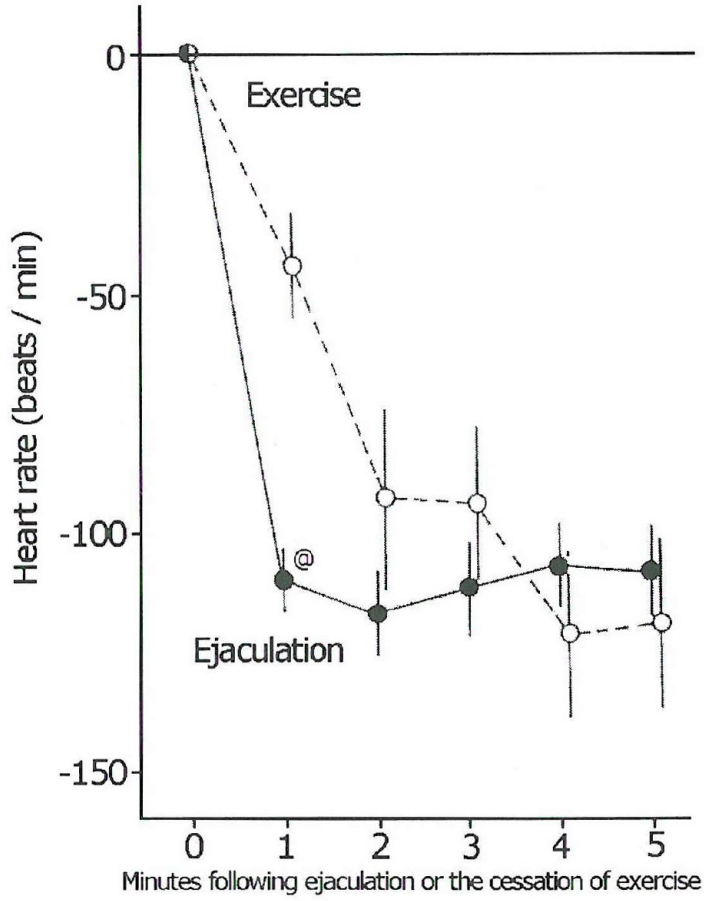

Fig. 3 Mean changes in heart rate relative to heart rate at the end of ejaculation or exercise. The data respent a total of 18 ejaculation or exercise bouts (mean±SE).
@ $p<0.001$ vs. Exercise group

an increase in heart rate during ejaculation is not caused by the act of copulation, but by the hyperfunction of the sympathetic nervous system involved in ejaculation. It is a well-known fact that an injury to the sympathetic nervous system impairs ejaculation, thus suggesting that a strong but transient excitation of the sympathetic nervous system plays an important role in ejaculation.

In addition, Yohimbine, an α_2-adrenoceptor antagonist, has been reported to enhance the copulatory behaviors of castrated or aged male rats, and to attenuate or reverse antisexual behaviors induced by clonidine, epinephrine or somatostatin. Furthermore, neuropeptide Y (NPY), which is also released by the sympathetic nervous system, causes suppressed copulatory behaviors observed in aged rats *(Clark 1995)*. Hence, ejaculation and desire for copulation are believed to be regulated by different physiological mechanisms.

Summary

We have studied the physiological and behavioral responses in male rats to copulation and exercise. For this purpose, electrocardiographys (ECGs) were recorded from conscious and unrestrained rats using radiotelemetry system. Heart rate during copulation rose sharply following the induction of a receptive female, showed a peak of about 520 bpm during each ejaculation series, and then rapidly decreased. To compare the rate of decrease after ejaculation with that following vigorous exercise, we run male rats on a motor wheel until heart rate became to the same value during ejaculation. Following the cessation of exercise, heart rate decreased gradually. The possible role of the autonomic nervous system in the changes of heart rate during copulation and exercise is discussed.

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