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Antagonism of Estrogen-Induced Lordosis by Corticosterone in Adrenalectomized-Ovariectomized Female Rats and Mice

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DECATANZARO, D., R. P. KNIPPING AND B. B. GORZALKA. *Antagonism of estrogen-induced lordosis by corticosterone in adrenalectomized-ovariectomized female rats and mice.* PHARMAC. BIOCHEM. BEHAV. 15(5) 761–766, 1981.— Previous experimentation has established that adrenalectomy can facilitate lordosis in ovariectomized estrogen-primed female rats. Experiment 1 examined the role of adrenal steriods in this effect, the results indicating an attenuation with chronic corticosterone but not with desoxycorticosterone or progesterone administration. Experiment 2 established a dose-response curve for this corticosterone effect. Experiments 3 and 4 indicated that corticosterone administration inhibits lordosis when it precedes estrogen administration. Experiment 5 demonstrated that corticosterone also inhibits estrogen-induced lordosis in mice. These data suggest that corticosterone may modulate estrogen-mediated behavior in rodents.

Corticosterone Estrogen Lordosis Female sexual behavior Adrenalectomy

RECENT data suggest a role of adrenal corticosteroids in the regulation of estrogen-induced sexual receptivity in female rats. Specifically, a number of studies indicate that adrenalectomized-ovariectomized females more frequently show a lordosis reflex when estrogen-primed and presented to sexually active males than do adrenally-intact ovariectomized females [5, 6, 7, 10, 11, 16]. Although one study has reported a contrary effect of adrenalectomy [22], autopsy revealed substantial regeneration of adrenal cortical tissues in the subjects employed. Chronically higher levels of ACTH accompany adrenalectomy [4,12], but this hormone may not be directly involved in a facilitation of lordosis by adrenalectomy, in that ACTH cannulated into the ventricles of the brain suppresses lordosis and ACTH delivered peripherally only affects lordosis in the presence of the adrenal [7]. However, chronic administration of the synthetic corticosteroid, dexamethasone, does substantially inhibit estrogen-induced lordosis in female rats [6]. Also, one experiment suggested that chronic administration of corticosterone can reduce estrogen-induced lordosis in adrenalectomized-ovariectomized females to levels similar to those of adrenally-intact ovariectomized females [6]. In sum, these previous studies suggest an inhibitory role of adrenal corticosteroids in the control of female receptivity.

The present study aimed to verify this role of adrenal hormones in lordosis and to examine some basic parameters of their action in the modulation of this behavior. This included a comparison of the effects of three adrenal corticosteroids on lordosis, examinations of dose and regimen of the most effective of these steroids, corticosterone, and a test of the species generality of corticosterone-induced inhibition of estrogen-induced lordosis.

EXPERIMENT 1

An elevation in estrogen-induced receptivity after adrenalectomy is consistent with the notion that some adrenal product acts to inhibit receptivity. Previous data [6] implicated corticosterone, but the inhibitory effect of this substance on lordosis was much less than that of the synthetic glucocorticoid, dexamethasone, and did not entirely reverse the effect of adrenalectomy. These data suggested, among several alternatives, that other adrenal steroids might be involved. Indeed, although acute release of progesterone

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facilitates lordosis, some evidence suggests that chronic progesterone treatment suppresses this behavior [9]. Also, desoxycorticosterone may share some of the behavioral effects of progesterone [15], and has some affinity for estrogen target tissues [24] as does dexamethasone [19]. This previously led to speculation that a number of adrenal steroids might modulate estrogen-induced lordosis [6]; in the present experiment this notion was explicitly tested.

METHOD

Subjects and surgery

Sprague-Dawley female rats were obtained from Canadian Breeding Farms, St. Constant, Quebec. When these females were at weights of 220 to 250 g, all were bilaterally ovariectomized and about half were also bilaterally adrenalectomized under 40 mg/kg sodium pentobarbital (Nembutal, Abbott) anaesthetic supplemented where necessary with ether. All surgery was performed via bilateral lumbar incisions. Adrenalectomized-ovariectomized females were given continuous access to 0.9% saline solution in lieu of water immediately following surgery and throughout the course of the experiment. Animals were group-housed in wire-mesh cages in a room maintained at 21±1°C.

Procedure

The experiment was conducted in three stages, with a different hormone tested in each stage, and thus oil-vehicle control conditions were repeated for each hormone. In all cases the first test of lordosis occurred at least 3 weeks following surgery. One week, 48 hr and 24 hr prior to testing, each female was given 10 μg estradiol benzoate in 0.05 cc peanut oil SC. A different set of animals was employed in each stage of the experiment. In the first stage, 12 adrenalectomized-ovariectomized and 12 ovariectomized females were each given 500 μg corticosterone in 0.05 cc peanut oil SC every 24 hr beginning 49 hr before the second estrogen injection. Similarly, 14 adrenalectomized-ovariectomized and 11 ovariectomized females received 0.05 cc oil vehicle injections at these times. In the second stage, the same procedure was repeated with 12 adrenalectomized-ovariectomized and 12 ovariectomized females receiving an identical regimen of 500 μg desoxycorticosterone acetate, and 11 adrenalectomized-ovariectomized and 11 ovariectomized females receiving oil vehicle. In the third stage, 14 adrenalectomized-ovariectomized and 13 ovariectomized females received injections of 500 μg progesterone, whereas 13 adrenalectomized-ovariectomized and 11 ovariectomized females received oil injections. All steroids were purchased from Steraloids, Inc.

Behavioral Testing

Measurement of lordosis behavior occurred in a dimly illuminated room separate from the animal colony and also maintained at 21±1°C. This involved presentation of females individually to stud male rats in cylindrical pyrex testing arenas measuring 45 cm in height with a diameter of 29 cm. Stud males were given brief access to fully receptive females (each given 10 μg estradiol benzoate 48 hr and 500 μg progesterone 6 hr before presentation) just prior to sessions with experimental females. These males were employed during the dark phase of their (reversed) light cycle. Each female was placed with a male until ten mounts accompanied by pelvic thrusting had occurred. If a male did not mount, the female was placed in another arena containing a different male. The female's response to a mount was categorized as either a lordosis response, consisting of a full arching of the back [13], or no lordosis, consisting of any other response or no response. A lordosis quotient was calculated as the percentage of mounts resulting in a lordosis response.

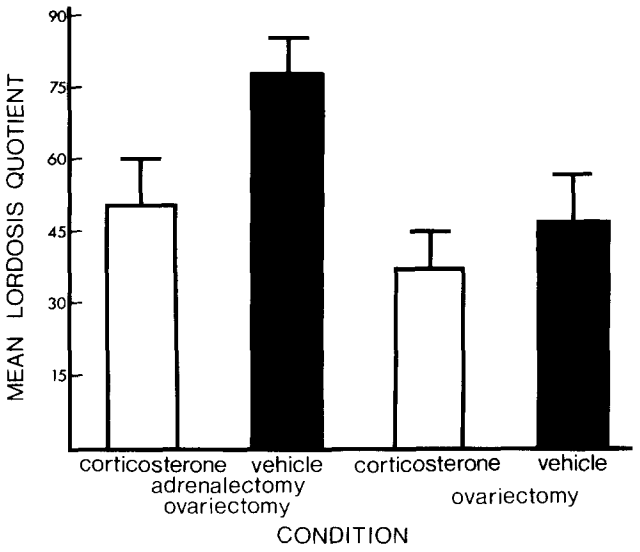

FIG. 1. Mean lordosis quotients (±SE) for estrogen-treated adrenalectomized-ovariectomized and ovariectomized female rats given corticosterone or oil vehicle in Experiment 1.

TABLE 1

MEAN LORDOSIS QUOTIENTS (±SE) FOR FEMALE RATS CHRONICALLY ADMINISTERED ADRENAL STEROIDS IN EXPERIMENT 1

	Adrenalectomized-Ovariectomized	Ovariectomized
Desoxycorticosterone	59.17 ±7.43	35.83 ± 9.25
Vehicle	60.00 ±7.74	38.18 ±11.51
Progesterone	83.57 ±4.14	68.46 ± 7.15
Vehicle	78.46 ±6.59	51.82 ±10.94

RESULTS AND DISCUSSION

Figure 1 gives the results obtained for corticosterone, whereas data for desoxycorticosterone and progesterone are given in Table 1. Only in the case of corticosterone did there appear to be a substantial effect of the hormone treatment. A separate 2 (adrenalectomized-ovariectomized vs ovariectomized) × 2 (hormone vs vehicle) analysis of variance was conducted for each hormone treatment and its controls. Analyses in this and subsequent experiments were con-

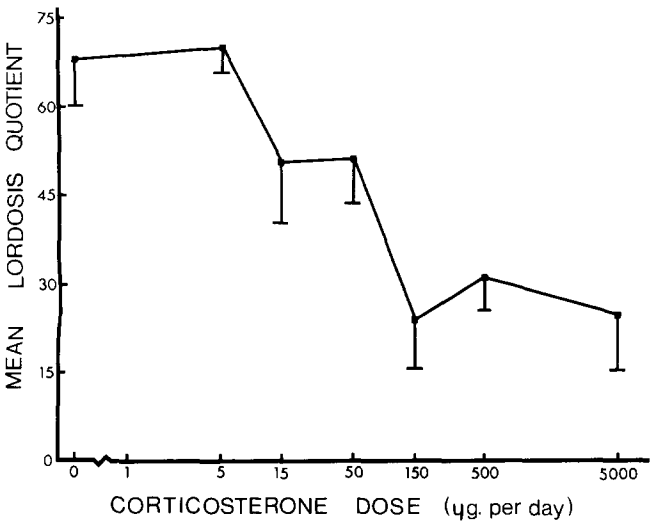

FIG. 2. Mean lordosis quotients (±SE) for estrogen-treated adrenalectomized-ovariectomized female rats given various daily doses of corticosterone in Experiment 2.

ducted on an angular (arcsin) transformation of the raw data, which is appropriate for percentage data [17]. The analysis for corticosterone revealed significant main effects of surgery, $F(1,45)=6.99$, $p=0.0112$, and of the hormone, $F(1,45)=4.78$, $p=0.0340$, but no significant interaction. Subsequent Newman-Keuls comparisons ($p<0.05$) using the unequal n's method of Kramer [18] indicated that the adrenalectomized-ovariectomized vehicle group significantly differed from all other groups. The analysis of variance for desoxycorticosterone revealed a significant main effect of surgery, $F(1,42)=4.60$, $p=0.0378$, but no other significant effects. Similarly, the analysis of variance for progesterone revealed a significant main effect of surgery, $F(1,47)=7.36$, $p=0.0093$, but no other significant effects.

These results suggest that corticosterone acts to inhibit estrogen-induced lordosis, especially in adrenalectomized females. Comparable effects of other steroids secreted by the adrenal, desoxycorticosterone and progesterone, are apparently absent. It seems plausible that adrenalectomy may facilitate estrogen-induced lordosis in ovariectomized females because it removes the source of endogenous corticosterone, whereas chronic administration of exogenous corticosterone reverses this behavioral effect of adrenalectomy.

EXPERIMENT 2

Experiment 1 confirmed that chronic administration of 500 μg corticosterone could reduce estrogen-induced lordosis in adrenalectomized-ovariectomized females. The present experiment examined the effects of various doses of corticosterone.

METHOD

Experimental animals consisted of female Sprague-Dawley rats obtained from Blue Spruce Farms, Altamont, NY. Adrenalectomies and ovariectomies were performed on these animals when their weight was 220–240 g. Animals were housed and maintained as in Experiment 1.

TABLE 2

MEAN LORDOSIS QUOTIENTS (±SE) OF ADRENALECTOMIZED-OVARIECTOMIZED FEMALE RATS UNDER DIFFERENT CORTICOSTERONE REGIMENS IN EXPERIMENT 3

Vehicle Control	62.50 ± 5.66
Corticosterone Post-Estrogen	46.67 ± 7.11
Corticosterone Pre-Estrogen	16.67 ± 5.95
Corticosterone Pre- and Post-Estrogen	16.67 ± 8.01

Estradiol benzoate was administered to all animals according to the regimen of Experiment 1. Animals were distributed across seven conditions involving different daily doses of corticosterone: 0, 5, 15, 50, 150, 500, 5000 μg per animal with sample sizes of 10 per condition except for the 150 μg condition where there were 9 subjects. These injections were given SC in 0.05 cc of vehicle. In this and subsequent experiments propylene glycol served as the steroid vehicle since corticosterone dissolves more readily in this vehicle than in oil; in the 5000 μg dose condition the solution was heated briefly prior to injection. The first corticosterone injection was given immediately following the initial dose of estrogen. Subsequent injections were given every 24 hr, with the sixth and seventh (final) such injections occurring immediately following injections of estrogen.

The procedure in behavioral testing was identical to that of Experiment 1, except that testing arenas in this and subsequent experiments were made of Plexiglas and measured 33×33×60 (height) cm. Also in this and subsequent experiments, a procedure was initiated that made the experimenter recording behavior blind to the animal's treatment condition. This involved a second experimenter labelling the animals in code before transferring them to the observer.

RESULTS AND DISCUSSION

Figure 2 presents lordosis quotients for all conditions. There was a clear inhibition of lordosis when the daily dose of corticosterone was 150 μg or greater. A one-way analysis of variance conducted on these data indicated a significant effect, $F(6,62)=6.17$, $p<0.0001$. Newman-Keuls comparisons indicated that the 150, 500 and 5000 μg conditions differed from the 0 and 5 μg conditions. These results suggest that the inhibitory effect of corticosterone upon lordosis behavior increases in a dose-dependent manner, but that increasing the dose above 150 μg daily does not enlarge the effect.

EXPERIMENT 3

The previous experiments established that chronic corticosterone administration can inhibit lordosis. It is conceivable that only some subset of the corticosterone injections given in these experiments was necessary and sufficient to produce this inhibitory effect. The present experiment and Experiment 4 examined the effects of different corticosterone regimens on estrogen-induced lordosis.

METHOD

Sprague-Dawley females were obtained and prepared as in Experiment 2. All animals received 10 μg estradiol benzoate 7 days and 20 μg estradiol benzoate 48 hr prior to

remains conceivable that corticosterone can alter lordosis through some mechanism not involving estrogen receptors when administered at long intervals before testing.

ACKNOWLEDGEMENTS

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REFERENCES

1. Ahlenius, S., J. Engel, H. Eriksson and P. Sodersten. Effects of tetrabenazine on lordosis behaviour and on brain monoamines in the female rat. *J. Neural Transm.* **33:** 155–162, 1972.
2. Ahlenius, S., J. Engel, H. Eriksson, K. Modigh and P. Sodersten. Importance of central catecholamines in the mediation of lordosis behaviour in ovariectomized rats treated with estrogen and inhibitors of monoamine synthesis. *J. Neural Transm.* **33:** 247–255, 1972.
3. Ahlenius, S., J. Engel, H. Eriksson, K. Modigh and P. Sodersten. Involvement of monoamines in the mediation of lordosis behavior. In: *Sexual Behavior: Pharmacology and Biochemistry*, edited by M. Sandler and G. L. Gessa. New York: Raven Press, 1975, pp. 137–145.
4. Cox, G. S., J. R. Hodges and J. Vernikos. The effect of adrenalectomy on the circulating level of adrenocorticotropic hormone in the rat. *J. Endocr.* **17:** 177–188, 1958.
5. Davidson, J. M., C. H. Rodgers, E. R. Smith and G. J. Bloch. Stimulation of female sexual behavior in adrenalectomized rats with estrogen alone. *Endocrinology* **82:** 193–195, 1968.
6. deCatanzaro, D. and B. B. Gorzalka. Effects of dexamethasone, corticosterone, and ACTH on lordosis in ovariectomized and adrenalectomized-ovariectomized rats. *Pharmac. Biochem. Behav.* **12:** 201–206, 1980.
7. deCatanzaro, D., D. S. Gray and B. B. Gorzalka. Effects of acute central and peripheral $ACTH^{1-24}$ administration on lordosis behavior. *Physiol. Behav.* **26:** 207–213, 1981.
8. Dunn, A. J. and W. H. Gispen. How ACTH acts on the brain. *Biobehav. Rev.* **1:** 15–23, 1977.
9. Edwards, D. A., R. E. Whalen and R. D. Nadler. Induction of estrus: Estrogen-progesterone interactions. *Physiol. Behav.* **3:** 29–33, 1968.
10. Eriksson, H. and P. Sodersten. A failure to facilitate lordosis behavior in adrenalectomized and gonadectomized estrogen-primed rats with monoamine-synthesis inhibitors. *Hormones Behav.* **4:** 89–97, 1973.
11. Everitt, B. H., K. Fuxe, T. Hökfelt and G. Jonsson. Studies on the role of monoamines in the hormonal regulation of sexual receptivity in the female rat. In: *Sexual Behavior: Pharmacology and Biochemistry*, edited by M. Sandler and G. L. Gessa. New York, Raven Press, 1975, pp. 147–159.
12. Gemzell, C. A., D. C. vanDyke, C. A. Tobias and M. M. Evans. Increase in the formation and secretion of ACTH following adrenalectomy. *Endocrinology* **49:** 325–336, 1951.
13. Gorzalka, B. B. and G. J. Mogenson. Sexual Behavior. In: *The Neurobiology of Behavior: An Introduction*. edited by G. J. Mogenson, Hillsdale, NJ: Lawrence Erlbaum Associates, 1977, pp. 151–186.
14. Gorzalka, B. B. and R. E. Whalen. Inhibition not facilitation of sexual behavior by PCPA. *Pharmac. Biochem. Behav.* **3:** 511–513, 1975.
15. Gorzalka, B. B. and R. E. Whalen. The effects of progestins, mineralocorticoids, glucocorticoids, and steroid solubility on the induction of sexual receptivity in rats. *Hormones Behav.* **8:** 94–99, 1977.
16. Gray, D. S. and B. B. Gorzalka. Adrenal steroid interactions in female sexual behavior: A review. *Psychoneuroendocrinology* **5:** 157–175, 1980.
17. Kirk, R. E. *Experimental Design: Procedures for the Behavioral Sciences*. Belmont, CA: Brooks/Cole, 1968.
18. Kramer, C. Y. Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics* **12:** 307–310, 1956.
19. Lisk, R. D. and L. A. Reuter. Dexamethasone: Increased weights and decreased [^{3}H] estradiol retention of uterus, vagina and pituitary in the ovariectomized rat. *Endocrinology* **99:** 1063–1070, 1976.
20. Parvez, H. and S. Parvez. The regulation of monoamine oxidase activity by adrenal cortical steroids. *Acta endocr.* **73:** 509–517, 1973.
21. Rastogi, R. B. and R. L. Singhal. Evidence for the role of adrenocortical hormones in the regulation of nonadrenaline and dopamine metabolism in certain brain areas. *Br. J. Pharmac.* **62:** 131–136, 1978.
22. Ring, J. R. The hormonal induction of mating responses in the spayed-adrenalectomized female rat. *Endocrinology* **37:** 237–244, 1945.
23. Veals, J. W., C. A. Korduba and S. Symchowicz. Effect of dexamethasone on monoamine oxidase inhibition by iproniazid in rat brain. *Eur. J. Pharmac.* **41:** 291–299, 1977.
24. Verlardo, J. T. The actions of steroid hormones on estradiol-17β in uterine growth and enzymorphology. In: *Hormonal Steroids*, Vol. 1, edited by L. Martini and A. Pecile. New York: Academic Press, 1964, pp. 463–490.
25. Ward, I. L., W. R. Crowley, F. P. Zemlan and D. L. Margules. Monoaminergic mediation of female sexual behavior. *J. comp. physiol. Psychol.* **88:** 53–61, 1975.
26. Zemlan, F. P., I. L. Ward, W. R. Crowley and D. L. Margules. Activation of lordotic responding in female rats by suppression of serotonergic activity. *Science* **179:** 1010–1012, 1973.

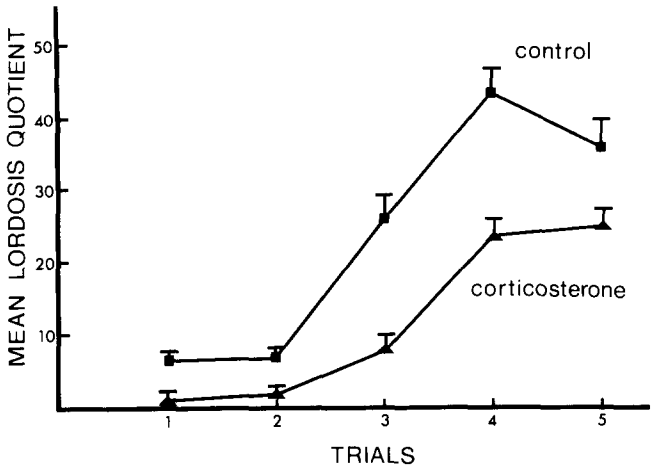

FIG. 3. Mean lordosis quotients (±SE) for estrogen-treated adrenalectomized-ovariectomized female mice given daily corticosterone or propylene glycol vehicle in Experiment 5.

following behavioral measurement. Four animals in each condition died before the experiment was completed and were excluded from all analyses.

Behavioral Testing

Measurement of lordosis was similar to that conducted for rats, except that a lordosis response was defined as the maintenance of a rigid posture that allowed the male to mount completely and intromit if he continued thrusting. Any other response was recorded as no lordosis; usually a nonreceptive female would vocalize and attempt to escape from a mounting male. Testing chambers were 4-liter Pyrex beakers. Stud males had had several hours of previous sexual experience and did not require immediate pre-exposure to fully receptive females. As in Experiments 2, 3 and 4, the experimenter recording behavior was blind to the treatment conditions from which particular subjects were derived.

RESULTS AND DISCUSSION

Figure 3 gives the mean lordosis quotients for the two conditions. The mean performance of vehicle-treated females exceeded that of corticosterone-treated females in each of the repeated measures. There was a clear trend in both conditions toward increased receptivity over trials. An analysis of variance, treating the trial factor as being within subjects, indicated significant effects of the corticosterone treatment, $F(1,30)=5.22$, $p=0.0296$, and of trials, $F(4,120)=10.52$, $p<0.0001$. These data suggest that corticosterone inhibits estrogen-induced lordosis after adrenalectomy in mice as it does in rats.

GENERAL DISCUSSION

These experiments indicate that corticosterone may play an inhibitory role in the determination of female sexual receptivity. They confirm findings that adrenalectomy can facilitate estrogen-induced receptivity [5, 6, 7, 10, 11, 16], and demonstrate that corticosterone, but not desoxycorticosterone nor progesterone administration can reverse this effect. An inhibition of estrogen-induced lordosis by corticosterone administration in adrenalectomized-ovariectomized rats occurs at moderate doses, but does not increase with very high doses. The effect requires that corticosterone be administered a number of days before receptivity tests and probably requires that corticosterone be given prior to estrogen administration. The effect is not limited to a single species, but rather occurs in at least mice and rats.

Although chronic treatment with progesterone and desoxycorticosterone failed to inhibit lordosis induced by estrogen alone, other doses and regimens can produce different results. For example, it has been reported that 10 days of progesterone treatment (5 mg) inhibits lordosis induced by a combination of estrogen and progesterone [9]. Nonetheless it appears that with estrogen administration alone, only chronic corticosterone pretreatment is inhibitory, at least in the adrenalectomized-ovariectomized rat. The relative potency of the three corticosteroids when employed as inhibitors in the current paradigm is precisely the reverse of their facilitatory potencies. When administered after estrogen treatment as an acute injection 3–5 hr before behavioral testing, both progesterone and desoxycorticosterone facilitate lordosis whereas corticosterone is completely ineffective [15]. Whether or not this inverse potency relationship between facilitation and inhibition generalizes to other corticosteroids affecting estrogen-induced lordosis, awaits further experimentation.

A reduction of estrogen-induced lordosis by corticosterone is of potential importance in that no previous studies indicate that glucocorticoids interfere with estrogen-induced behavior. Several hypotheses can be advanced. Among these is the possibility that corticosterone affects lordosis through its effects on brain monoamine activity. Evidence indicates that activity of catecholamines, especially dopamine, reduces lordosis behavior [1, 2, 3, 11]. Similarly, there is evidence that activity of serotonin decreases lordosis [2, 11, 25, 26], although not all studies are consistent on this point [14]. There is complementary evidence that adrenalectomy facilitates and glucocorticoids inhibit the activity of monoamine oxidase, an enzyme that metabolizes and inactivates both catecholamines and serotonin [20, 21, 23]. Accordingly, adrenalectomy may decrease activity of catecholamines and serotonin, thereby increasing lordosis, whereas corticosterone may increase activity of catecholamines and serotonin, thereby inhibiting lordosis. However, adrenalectomy also elevates ACTH levels [4,12], and elevated ACTH may increase catecholamine activity [8]. Corticosterone administration, which through feedback mechanisms should lower ACTH levels, reduced lordosis behavior in adrenalectomized-ovariectomized females in our laboratories. A role of ACTH in the effects of adrenalectomy and corticosterone on lordosis seems unlikely but cannot be entirely excluded; although ACTH administered acutely into the ventricular system of the brain can suppress lordosis [7], the effect of chronic central administration of ACTH on lordosis has not been investigated.

Another possibility is that corticosterone interferes with the activity of estrogen in inducing lordosis. To the best of our knowledge, there is no evidence that corticosterone has any anti-estrogenic activity on estrogen binding sites. Nonetheless, the results of Experiments 3 and 4 suggest that the temporal relationship of corticosterone administration to estrogen administration may be critical for the inhibitory effect of the adrenal hormone to appear. However, those experiments do not support strong conclusions about mechanisms underlying the corticosterone effect; other regimens of corticosterone and estrogen need to be investigated, and it

remains conceivable that corticosterone can alter lordosis through some mechanism not involving estrogen receptors when administered at long intervals before testing.

ACKNOWLEDGEMENTS

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REFERENCES

1. Ahlenius, S., J. Engel, H. Eriksson and P. Sodersten. Effects of tetrabenazine on lordosis behaviour and on brain monoamines in the female rat. *J. Neural Transm.* **33:** 155–162, 1972.
2. Ahlenius, S., J. Engel, H. Eriksson, K. Modigh and P. Sodersten. Importance of central catecholamines in the mediation of lordosis behaviour in ovariectomized rats treated with estrogen and inhibitors of monoamine synthesis. *J. Neural Transm.* **33:** 247–255, 1972.
3. Ahlenius, S., J. Engel, H. Eriksson, K. Modigh and P. Sodersten. Involvement of monoamines in the mediation of lordosis behavior. In: *Sexual Behavior: Pharmacology and Biochemistry*, edited by M. Sandler and G. L. Gessa. New York: Raven Press, 1975, pp. 137–145.
4. Cox, G. S., J. R. Hodges and J. Vernikos. The effect of adrenalectomy on the circulating level of adrenocorticotropic hormone in the rat. *J. Endocr.* **17:** 177–188, 1958.
5. Davidson, J. M., C. H. Rodgers, E. R. Smith and G. J. Bloch. Stimulation of female sexual behavior in adrenalectomized rats with estrogen alone. *Endocrinology* **82:** 193–195, 1968.
6. deCatanzaro, D. and B. B. Gorzalka. Effects of dexamethasone, corticosterone, and ACTH on lordosis in ovariectomized and adrenalectomized-ovariectomized rats. *Pharmac. Biochem. Behav.* **12:** 201–206, 1980.
7. deCatanzaro, D., D. S. Gray and B. B. Gorzalka. Effects of acute central and peripheral $ACTH^{1-24}$ administration on lordosis behavior. *Physiol. Behav.* **26:** 207–213, 1981.
8. Dunn, A. J. and W. H. Gispen. How ACTH acts on the brain. *Biobehav. Rev.* **1:** 15–23, 1977.
9. Edwards, D. A., R. E. Whalen and R. D. Nadler. Induction of estrus: Estrogen-progesterone interactions. *Physiol. Behav.* **3:** 29–33, 1968.
10. Eriksson, H. and P. Sodersten. A failure to facilitate lordosis behavior in adrenalectomized and gonadectomized estrogen-primed rats with monoamine-synthesis inhibitors. *Hormones Behav.* **4:** 89–97, 1973.
11. Everitt, B. H., K. Fuxe, T. Hökfelt and G. Jonsson. Studies on the role of monoamines in the hormonal regulation of sexual receptivity in the female rat. In: *Sexual Behavior: Pharmacology and Biochemistry*, edited by M. Sandler and G. L. Gessa. New York, Raven Press, 1975, pp. 147–159.
12. Gemzell, C. A., D. C. vanDyke, C. A. Tobias and M. M. Evans. Increase in the formation and secretion of ACTH following adrenalectomy. *Endocrinology* **49:** 325–336, 1951.
13. Gorzalka, B. B. and G. J. Mogenson. Sexual Behavior. In: *The Neurobiology of Behavior: An Introduction*. edited by G. J. Mogenson, Hillsdale, NJ: Lawrence Erlbaum Associates, 1977, pp. 151–186.
14. Gorzalka, B. B. and R. E. Whalen. Inhibition not facilitation of sexual behavior by PCPA. *Pharmac. Biochem. Behav.* **3:** 511–513, 1975.
15. Gorzalka, B. B. and R. E. Whalen. The effects of progestins, mineralocorticoids, glucocorticoids, and steroid solubility on the induction of sexual receptivity in rats. *Hormones Behav.* **8:** 94–99, 1977.
16. Gray, D. S. and B. B. Gorzalka. Adrenal steroid interactions in female sexual behavior: A review. *Psychoneuroendocrinology* **5:** 157–175, 1980.
17. Kirk, R. E. *Experimental Design: Procedures for the Behavioral Sciences*. Belmont, CA: Brooks/Cole, 1968.
18. Kramer, C. Y. Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics* **12:** 307–310, 1956.
19. Lisk, R. D. and L. A. Reuter. Dexamethasone: Increased weights and decreased [^{3}H] estradiol retention of uterus, vagina and pituitary in the ovariectomized rat. *Endocrinology* **99:** 1063–1070, 1976.
20. Parvez, H. and S. Parvez. The regulation of monoamine oxidase activity by adrenal cortical steroids. *Acta endocr.* **73:** 509–517, 1973.
21. Rastogi, R. B. and R. L. Singhal. Evidence for the role of adrenocortical hormones in the regulation of nonadrenaline and dopamine metabolism in certain brain areas. *Br. J. Pharmac.* **62:** 131–136, 1978.
22. Ring, J. R. The hormonal induction of mating responses in the spayed-adrenalectomized female rat. *Endocrinology* **37:** 237–244, 1945.
23. Veals, J. W., C. A. Korduba and S. Symchowicz. Effect of dexamethasone on monoamine oxidase inhibition by iproniazid in rat brain. *Eur. J. Pharmac.* **41:** 291–299, 1977.
24. Verlardo, J. T. The actions of steroid hormones on estradiol-17β in uterine growth and enzymorphology. In: *Hormonal Steroids*, Vol. 1, edited by L. Martini and A. Pecile. New York: Academic Press, 1964, pp. 463–490.
25. Ward, I. L., W. R. Crowley, F. P. Zemlan and D. L. Margules. Monoaminergic mediation of female sexual behavior. *J. comp. physiol. Psychol.* **88:** 53–61, 1975.
26. Zemlan, F. P., I. L. Ward, W. R. Crowley and D. L. Margules. Activation of lordotic responding in female rats by suppression of serotonergic activity. *Science* **179:** 1010–1012, 1973.