Intra-Uterine Nutrition and its Effects on Aggression

EDWARD S. HALAS, GAIL M. REYNOLDS AND HAROLD H. SANDSTEAD

Department of Psychology, University of North Dakota
and United States Department of Agriculture, Agricultural Research Service
Human Nutrition Laboratory, Grand Forks, ND 58201

(Received 21 March 1977)

HALAS, E. S., G. M. REYNOLDS AND H. H. SANDSTEAD. Intra-uterine nutrition and its effects on aggression. PHYSIOL. BEHAV. 19(5) 653–661, 1977. — Prenatal zinc deficiency and prenatal undernutrition were found to have adverse effects on the food consumption and weight gain of pregnant dams and their offspring. Pups whose dams suffered prenatal zinc deficiency (ZD) consumed less food and gained less weight than pups whose dams suffered prenatal undernutrition (PF). The PF pups consumed less food and gained less weight than pups whose dams were normally fed (AL). The ZD females at age 75 days were significantly more aggressive than the PF females, while the PF females were more aggressive than the AL females. At age 105 days, ZD females were significantly more aggressive than the PF and AL females. There were no differences in aggression between the PF and AL females at 105 days. Among the ZD, PF, and AL male offspring, there were no differences in aggression at either age level except that the 75 day old PF males were significantly less aggressive than the AL males. Thus prenatal malnutrition, especially zinc deficiency, seems to have differential effects on the aggressive tendencies of female and male offspring.

Prenatal malnutrition  Aggression  Agonistic behavior  Prenatal zinc deficiency  Intra-uterine nutrition
Trace elements  Prenatal undernutrition  Shock-induced aggression

IT HAS BEEN reported [10] that adult female rats whose dams suffered undernutrition or zinc deficiency during most of the latter third of pregnancy were significantly more aggressive than adult female rats whose dams were fed an adequate diet during the entire period of pregnancy. The implications of this study are twofold. One, severe undernutrition during the latter third of pregnancy may have long term deleterious effects on the behavior of the offspring. Two, prenatal zinc deficiency during the same interval may have an even greater adverse effect on the behavior of the offspring. In addition to behavioral deficits, prenatal zinc deficiency throughout the latter third of gestation severely impairs the growth of rat fetuses, and also decreases brain size and cerebral DNA, thus implying the presence of fewer neurons [17]. Severe zinc deficiency induced early in pregnancy causes central nervous system teratology [12] and depresses the utilization of thymidine by developing nervous tissue [13]. These findings in the rat may be of significance for humans because chemical analysis of diets consumed by some women in the United States has revealed levels of zinc intake substantially below levels thought desirable for human pregnancy [26]. In addition studies of factors which influence the availability of dietary zinc for absorption [18,22] are consistent with the interpretation that dietary zinc is less available from diets high in cereals and vegetables and more available from diets rich in meats and dairy products. The former diets are less expensive and therefore more likely to be consumed by the poor. While the impact of such maternal diets on the zinc nutriture of human fetuses is unknown, an association between low plasma zinc levels and complications of pregnancy, including congenital anomalies, has been reported [14]. It has been speculated that some of the women in this latter study had dietary zinc deficiency.

In this present report we describe shock-induced aggression studies in both male and female rats which were similar in design to those referred to above [10]. These studies were conducted to replicate the above study in females and to ascertain if similar findings also occur in males.

EXPERIMENT 1

Experiment 1 studies the effects of prenatal zinc deficiency (ZD) and prenatal undernutrition (PF) in 75 day old female rats.

METHOD

Animals

Twenty-four Long-Evans rats were purchased from the

---

1 Supported in part by the United States Department of Agriculture Cooperative Agreement 12-14-100-11, 178 (61), Amendment 1.
2 Reprint requests should be sent to Dr. E. S. Halas, Department of Psychology, University of North Dakota, Grand Forks, ND 58201.
3 Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.
Charles River Company. Sixteen dams were bred 24 hr prior to the remaining eight. The latter eight dams (PF) were individually paired with eight dams in the former group who were made zinc deficient (ZD). The remaining eight dams were used in the ad libitum fed group (AL).

**Apparatus**

Each pair of rats was tested for aggressive behavior in a clear Plexiglas box measuring 32.0 x 25.5 x 30.5 cm. The grid floor consisted of 0.3 cm stainless steel rods spaced 1.9 cm from center to center. A Grason-Stadler Model 700 shock generator was used to electrify the grid. The Plexiglas chamber was placed inside a box 80 cm high, 61 cm deep and 80 cm wide. Two fans provided intake and exhaust ventilation.

**Procedure**

Starting on the morning of the 14th day of pregnancy, 8 dams (ZD) were fed a biotin-enriched 20% sprayed egg white diet which contained less than 1 μg zinc/g (TD 71305; Teklad Mills, Madison, WI) and deionized water. Since zinc deficiency causes anorexia, the eight PF dams were fed the amount of diet their individual ZD pair mates had consumed on the previous day. The PF dams were given drinking water containing 50 μg zinc per ml. The third group of 8 dams (AL) were given the same diet ad libitum along with the zinc supplemented water. On the morning of the 20th day of pregnancy, all dams were taken off the zinc deficient diet and given Purina Laboratory Chow ad libitum and tap water. Twenty-four hr after delivery, all litters were reduced to the 9 most healthy appearing pups in the litter. Food consumption of the dams was recorded daily and their weight gain was recorded every fourth day. The pups were weaned on the 21st day and their food consumption and weight gain were recorded periodically from Day 22 to Day 40. The dams and their pups were housed in plastic cages in a temperature and humidity controlled room.

When the pups were 75 days old, 10 females were randomly selected from each group. However, each litter contributed at least one female. All rats were then individually housed in stainless steel cages. To habituate the rats to handling and transportation, all rats were given 5 days of experience in an open field box. Several cages with their rats were removed from the rack and placed on a small cart and transported from the colony room to the experimental room. The cart and the cages remained in the hallway while each rat was individually placed in the open field box for 5 min. After all rats had finished the open field experience, the cart was returned to the colony room and the cages put back in the rack.

The aggression experiment was started when the rats were 82 days old. The 10 animals in each group were divided into 5 pairs for a total of 15 pairs. A ZD female was always paired with a ZD female of a different litter and was always paired with the same female throughout the experiment. The PF and AL females were treated the same way. Each pair was given 25 shocks per day for 12 days. The scrambled shock was set at 1.6 mA for the odd numbered days and 1.0 mA for the even numbered days. The rats were run every day except on the weekend. The duration of all shocks was 0.5 sec and spaced 5.0 sec apart. The 15 pairs of rats were run in a counter balanced order each day. The daily sessions were videotaped and evaluated by three judges who counted aggressive attacks by each pair for each day [11]. Aggressive attacks were defined as directed movement towards the opponent which resulted in contact, including at least one of the following responses: biting, sparing, upright attack posturing, or supine submissive posturing adopted by the attacked rat [7]. All judgments were made independently and without knowledge of group origin of each pair. The training of the judges and their evaluation procedure has been described in detail elsewhere [11]. The reliability between judges for each day ranged from 0.94 to 0.99 for the 12 days.

Where it was appropriate to use a repeated measures statistic, the Friedman two way analysis of variance was used to determine the overall level of significance among the three groups. The Wilcoxon test was then used for multiple internal comparisons among the three groups of rats. Wherever it was not possible to use a repeated measures statistic, the Kruskal-Wallis test was used to determine the significant level of the three groups. The Mann Whitney U test was then used for multiple internal comparisons among the three groups of rats [15].

**RESULTS**

The food consumption of the dams is shown in Fig. 1. Previous research has shown that it usually takes about three days for the zinc deficient diet to induce significant anorexia [17]. During the zinc deficient period, the ZD dams consumed significantly less food than the AL dams (p = 0.004). The PF dams were given the same quantity of the diet as was eaten by the ZD dams. The slight discrepancy in food consumption between the ZD and PF dams during the zinc deficient period was caused by individual dams in either group losing their litters during the lactation period and thus being dropped from the experiment. All figures and statistical analyses were based only on those dams that successfully raised their litter to 21 days of age. Five AL dams were successful in raising litters while 6 PF and 5 ZD dams succeeded. There were no differences in food consumption among the three groups of dams before (p = 0.20) or after the zinc deficient period (p = 0.30).

The mean weights of the dams are shown in Fig. 2. Prior to the zinc deficient period, there were no significant differences among the three groups of dams (p = 0.30).
FIG. 2. Mean weight of the dams during the prenatal and postnatal periods. Day 0 is the day of delivery.

FIG. 3. Mean food consumption of the pups from age 23 through 40 days. The numbers in the parentheses are the percentage of males in each group.

FIG. 4. Mean weight of the pups from birth through 40 days of age.

FIG. 5. The daily curves show the percent of aggressive responses for each group of 75 day old females at 1.0 and 1.6 mA. The overall significance level for the three groups is given below the curves. The bar graphs show the mean level of aggression for each group at 1.0 and 1.6 mA. The level of significance between the groups is shown in brackets below the bar graphs. Only those probabilities where $p = 0.10$ or less are shown.

From the 14 to the 22 day of pregnancy, there were significant differences in mean weight gain among the three groups of dams ($p = 0.01$). The AL dams gained significantly more weight than the PF dams ($p = 0.002$) and the PF dams gained more weight than the ZD dams ($p = 0.041$). During the postpartum period, there were no differences in weight among the three groups of dams.

Food consumption among the three groups of pups (Fig. 3) was significantly different ($p = 0.001$). The AL pups consumed significantly more food than the PF pups ($p = 0.01$) and the PF pups consumed significantly more food than the ZD pups ($p = 0.005$). The numbers in the parentheses in Fig. 3 give the percentage of males to the total number of pups for all litters in each group.

The mean weight of the pups are shown in Fig. 4. From birth to the 40 day of life, there were significant differences in weight among the three groups of pups ($p = 0.001$). The ZD pups weighed significantly less than either the PF or AL pups ($p = 0.005$) while the AL pups weighed significantly more than the PF pups ($p = 0.01$). At the beginning of the aggression experiment, the mean weight and standard deviation of the ZD females were 190 ± 21.1 g while the PF and AL females were 199 ± 21.4 and 212 ± 18.6 g respectively. The weight difference among the three groups of females was not significant.

Figure 5 illustrates the level of aggression among the
FIG. 6. Comparison of the mean level of aggression across all 12 days for each group. The overall significance level for the three groups is given above the bars. The level of significance between the groups is shown in brackets below the bar graphs. The 75 day old females were in Experiment 1, while the 75 day old males were in Experiment 2. Experiments 3 and 4 had 105 day old females and males respectively.

The number shown below each group of curves is the overall probability value for the three groups of rats computed by the Friedman two way analysis of variance. The curves show the day by day data for each group while the bar graphs show the mean for all 6 days at each level of shock. The level of significance between groups is shown in brackets below the bar graphs. Only those probabilities p = 0.10 or less are shown. The ZD group was significantly more aggressive than either the PF or AL groups (p = 0.025) at 1.0 mA and more aggressive than the AL group (p = 0.025) at 1.6 mA. Although the PF rats were more aggressive than the AL rats at both levels of shock, the differences were not statistically significant. The mean level of aggression across all 12 days for each group is shown in the upper left quadrant of Fig. 6. Again the ZD females were significantly more aggressive than the PF (p = 0.01) and AL females (p = 0.005) while the PF females were significantly more aggressive than the AL females (p = 0.005).

**DISCUSSION**

It is apparent that prenatal nutrition had long term effects on the food consumption and weight gain of the female offspring and on their subsequent aggressive behavior as young adults. The ZD pups consumed significantly less food and gained less weight than either the PF or AL pups. The PF pups, who were prenatally undernourished, ate significantly less food and gained less weight than the AL pups. The level of aggression for the three groups followed the same group sequence. The ZD pups were significantly more aggressive than the PF and AL pups and the PF pups were significantly more aggressive than the AL pups.

**EXPERIMENT 2**

Since the data in Experiment 1 was in agreement with the results of a previously published study [10] which also used 75 day old females, it was decided to repeat the experiment using 75 day old males.

**METHOD**

**Animals**

Thirty-four Long-Evans from the Charles Rivers Company were matched by weight; 12 dams were assigned to the ZD group, 11 to the PF group, and 11 to the AL group. As before, the PF dams were bred 24 hr later and individually paired with the ZD dams.

**Apparatus**

The same equipment and apparatus as described in Experiment 1 was used in Experiment 2.

**Procedure**

The same procedures described in the previous experiment were used with the following exceptions. The zinc deficient diet was started on the morning of the 13th day of pregnancy and terminated on the morning of the 20th day. The male offspring were subjected to 0.8 and 1.3 mA of shock. Pilot studies in our laboratory suggested that the higher levels of shock used in the female experiment were not suitable for males. The other parameters of the shocks were the same as in the female experiment. Each group had 7 pairs of males for a total of 21 pairs. Every litter contributed at least 1 male. All males were given 5 days of open field experience starting at 75 days of age and the aggression experiment began 7 days later.

**RESULTS**

During the zinc deficient period (Fig. 7), the ZD dams consumed significantly less food (p = 0.001) than the AL dams. There was no significant difference in food consumption among the three groups of dams before (p = 0.80) or after (p = 0.80) the zinc deficient period. Prior to the zinc deficient period (Fig. 8), there was no significant difference in mean weight among the three groups (p = 0.30). During the zinc deficient period, the weight gain of the AL dams was significantly greater than the PF and ZD dams (p = 0.001). Both the PF and ZD dams continued to weigh less than the AL dams (p = 0.005) during the lactation period even though all three groups of dams were fed Purina Chow ad lib. Although the PF dams weighed more than the ZD dams during the zinc deficient period, the differences were not significant (p = 0.15). However, during the lactation period, the PF dams were significantly heavier than the ZD dams (p = 0.01).

Among the three groups of pups (Fig. 9), there were
significant differences in food consumption ($p = 0.001$). The ZD pups consumed less than either the PF ($p = 0.001$) or AL pups ($p = 0.005$). However the PF pups consumed significantly more food than the AL pups ($p = 0.001$) which is not a typical finding in our laboratory. Forty-eight percent of the AL pups were males while only 40% of the PF pups were males. Therefore the greater food consumption of the PF pups cannot be attributed to having a higher percentage of males. We have no reasonable explanation for this particular result.

There were significant differences in mean weight among the three groups of pups ($p = 0.001$). Despite consuming less food and having a smaller percentage of males (Fig. 10), the AL pups gained significantly more weight than the PF pups ($p = 0.005$). The ZD pups gained less weight than either the PF or AL pups ($p = 0.001$). At the start of the aggression experiment, the mean weight and standard deviation of the AL males were $349 \pm 52$ g while the PF and ZD males were $342 \pm 50$ and $335 \pm 44$ g, respectively.

There were no significant differences in the level of aggression among the three groups of males (Fig. 11) for either the low ($p = 0.142$) or high ($p = 0.142$) level of shock. The higher shock did increase the level of aggression within each group ($p = 0.025$). The 75 day old females (Fig. 5) also had a higher level of aggression for the higher shock but their results failed to reach statistical significance. For both the high and low shocks, the PF males were less aggressive than either the ZD or AL males. When all 12 days were combined, as was done with the females, the PF males were significantly less aggressive than the ZD and AL males ($p = 0.005$). These results can be seen in the lower left quadrant of Fig. 6.

**DISCUSSION**

Unlike the 75 day old females, the ZD and PF males were not significantly more aggressive than the AL males. On the contrary, the PF males were significantly less aggressive than the AL and the ZD males. Since the food consumption and weight gain of the dams and their pups were so similar to those observed in Experiment 1, the
FIG. 11. The daily curves show the percent of aggressive responses for each group of 75 day old males at 0.8 and 1.3 mA. The bar graphs show the mean level of aggression for each group at 0.8 and 1.3 mA.

difference in aggressive behavior of the males was most interesting and suggested further investigation.

EXPERIMENT 3

The results of Experiment 2 suggested that the male offspring of ZD and PF dams do not suffer the same behavioral effects of prenatal malnutrition as do the female offspring. To test this hypothesis, the female littermates of the males used in Experiment 2 were run in the aggression experiment. Furthermore, it was noted that the males were more aggressive than the females even though the shock levels were lower for the males. Therefore it was decided to measure the pain threshold of male and female rats.

METHOD

Fourteen females were randomly selected from each group of dams for a total of 21 pairs. Every litter contributed at least one female and each female was always paired with a female from a different litter of the same group. As in Experiment 1, the shock levels were 1.3 and 1.6 mA. The females began their open field experience at the age of 105 days and started the aggression experiment 7 days later. All other aspects of the experiment were the same as before.

Eight additional males and eight females were randomly chosen from each of the three dietary groups and tested for their level of pain threshold. The test procedure was similar to those described elsewhere [16]. The shocks were 0.2 sec

FIG. 12. The daily curves show the percent of aggressive responses for each group of 105 day old females at 1.0 and 1.6 mA. The bar graphs show the mean level of aggression for each group.

in duration and were presented at 30 sec intervals. Each rat was given 10 series of shocks in alternating ascending and descending order. A series consisted of shock intensities of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, and 0.8 mA. The level of shock which caused both rear feet to simultaneously jump off the grid was used as the definition of pain threshold.

RESULTS

The food consumption and weight gain of the dams and their offspring have already been presented in Experiment 2. The mean weight and standard deviation of the AL females were 265 ± 25 g at the start of the aggression experiment while the PF and ZD females were 250 ± 19 g and 257 ± 28 g, respectively.

Figure 12 illustrates the level of aggression for the 105 day old females. As in Experiment 1, the ZD females were significantly more aggressive (p = 0.025) than the PF and AL females at the 1.3 mA shock level. However the PF females were not significantly more aggressive than the AL females. At the 1.6 mA shock level, the ZD females were significantly more aggressive than the PF females (p = 0.025), and although the ZD rats were more aggressive than the AL rats, the results were not significant. All three groups were more aggressive at the higher level of shock, but only the difference between the shock levels for the AL group were significant (p = 0.025). When the data were analyzed across all 12 days, the ZD females were significantly more aggressive (p = 0.005) than the PF and the AL females (Fig. 6). There was no difference in aggression between the PF and AL rats.
Among the female rats, there were no significant differences in pain threshold \((p = 0.19)\). The pain or jump threshold for the AL females was 0.33 mA while the threshold for the PF and ZD females was 0.38 and 0.35 mA respectively. For the AL, PF, and ZD male rats, the thresholds were 0.48, 0.48, and 0.43 mA respectively. Again the differences were not significant \((p = 0.50)\).

**DISCUSSION**

The major difference in the aggressive behavior of 75 and 105 day old females can be readily seen in Fig. 6. For both age groups, the ZD females were significantly more aggressive than the PF and AL groups. However only the 75 day old PF rats were significantly more aggressive than the AL rats. There was no difference in aggression between the PF and AL females at age 105 days. These results suggest that prenatal zinc deficiency has long term effects on the aggressive tendencies of the female offspring while prenatal undernutrition (PF) seems to have a transitory effect on the aggressive behavior.

Although the females had the lowest pain threshold, it was the males who had the highest overall level of aggression (Fig. 6). This fact is even more interesting because the males were subjected to lower levels of shock (0.8 and 1.3 mA) than the females (1.0 and 1.6 mA). In addition, there were no significant differences in pain threshold among the females. These results suggest that the perception of pain was not a critical factor for the aggressive behavior.

**EXPERIMENT 4**

Prenatal zinc deficiency \((ZD)\) and undernutrition \((PF)\) did not appear to have any adverse effects on the aggressive behavior of 75 day old males. On the contrary, the PF males were significantly less aggressive than the normal AL males (Fig. 6). To determine if prenatal undernutrition or zinc deficiency have long term effects on the aggressive behavior of male rats, Experiment 2 was repeated using 105 day old males.

**METHOD**

Thirty Long-Evans rats were purchased from the Charles Rivers Co. These dams were matched by weight and then assigned to the ZD, PF, and AL groups. The zinc deficient diet was started on the morning of the 13th day of pregnancy and terminated on the morning of the 20th day of pregnancy. When the males were 105 days old, 14 were randomly selected from each group for a total of 21 pairs. They began their open field experience at that age and started the aggression experiment 7 days later. All other aspects of the experiment were the same as in Experiment 2.

**RESULTS**

The food consumption and weight gain of the dams are not shown because they were similar to those shown in Figs. 7 and 8. In experiment 4, the ZD dams consumed significantly less food \((p = 0.001)\) than the AL dams during the zinc deficient period. There were no significant differences in food consumption among the three groups of dams after \((p = 0.70)\) the zinc deficient period. The AL dams gained significantly more weight than either the PF \((p = 0.001)\) or ZD dams \((p = 0.001)\) during the zinc deficient period. Prior to the zinc deficient period, there were no significant differences in weight gain among the three groups \((p = 0.50)\). Afterwards, the AL dams gained significantly more weight than either the PF \((p = 0.025)\) or the ZD dams \((p = 0.025)\). There were no significant differences in weight gain between the PF and ZD dams.

Food consumption and weight gain of the pups were similar to those shown in Figs. 3 and 10. From Day 22 to 40, the ZD pups consumed significantly less food than the PF \((p = 0.005)\) and AL pups \((p = 0.005)\). The weight gain of the pups was essentially the same as those shown in Figs. 4 and 10. The ZD pups weighed less than the PF \((p = 0.005)\) and AL pups \((p = 0.005)\) while the PF pups weighed less than the AL pups \((p = 0.005)\). At the start of the aggression experiment, the AL males mean weight and standard deviation were 399 ± 17 g while the PF and ZD males were 384 ± 20 g and 376 ± 31 g, respectively.

As illustrated in Fig. 13, there were no significant differences in aggression among the three groups of males although all groups had a significantly higher level of aggression at the higher shock level \((p = 0.025)\). The analysis of the data across all 12 days again showed no differences in aggression among the three groups of males (Fig. 6).

In the interest of clarity and brevity, the data from the open field experience for the four experiments were not presented in detail because the activity of the ZD and PF rats (both males and females) were not significantly different from the AL rats. The data analyzed were
entrance into center squares, peripheral squares, total squares, frequencies of urine spots, and fecal boli. In addition, the frequency of rearing was recorded and analyzed for the fourth experiment. None of the probabilities reached the 0.10 level.

DISCUSSION

The biological and behavioral effects of prenatal zinc deficiency and prenatal undernutrition were complex but consistent across all four experiments. The results of Experiment 4 show that Prenatal ZD and PF did not increase the level of aggression in 105 day old males. As can be seen in Fig. 6, these results were in contrast to those of 75 and 105 day old females. Prenatal ZD significantly increased shock-induced aggression among both 75 and 105 day old females. Prenatal undernutrition increased the level of aggression for 75 day old females but not for 105 day old females. From age 75 to 105 days, it was the AL females which displayed the greatest increase in aggression. The PF females reached a high level of aggression at age 75 days and showed no increase at age 105 days. The ZD females had the highest level of aggression at age 75 days and then increased their level of aggression at age 105 days. These results suggest that prenatal malnutrition causes 75 day old female rats to be much more aggressive than is normal for their age. With advancing age, the PF females do not noticeably increase their level of aggression which allows the AL females to catch up. The ZD females, however, continued to increase their level of aggression which suggests that the effects of prenatal zinc deficiency were more severe and more permanent than the prenatal undernutrition. It should be remembered, however, that zinc deficiency, because of anorexia, is a dual deficiency syndrome involving both undernutrition and zinc deficiency. Ideally it would be best to experimentally produce zinc deficiency in isolation but that has not been possible to date. Nevertheless it is possible to gain some understanding of the effects of zinc deficiency by comparing the results of the ZD and PF groups.

Compared to 75 day old females, prenatal undernutrition had an opposite effect on 75 day old males. These males were significantly less aggressive than normal adult males. At age 105, there were no differences in aggression between the PF and AL males. As expected, the males were consistently more aggressive than the females even though the levels of shock given the males were lower. In summary, the results suggest that prenatal malnutrition has differential behavioral effects on male and female rats. The behavioral findings are supported by the biological data where the food consumption and weight gain of both the dams and their pups were adversely affected by prenatal zinc deficiency and prenatal undernutrition.

Thus these results show that adult female rats who suffered prenatal zinc deficiency or prenatal undernutrition were significantly more aggressive than adult female rats whose dams were adequately nourished. What is not known is the intervening mechanism or injury that is directly related to the aggressive behavior in the adult rat. There are two broad categories of intervening variables, behavioral and physiological, that should be considered. The behavioral mechanisms would include maternal-infant interaction, early handling, isolation vs. group living, hyperactivity, etc., while the physiological variables would include neurotransmitters, hormones, pheromones, androgens, lesions, pain, etc. Since the males and females in the four experiments responded differently to the experimental conditions, the results would suggest an insult to a physiological mechanism for the following reasons. It would be difficult to attribute the results to maternal-infant interaction because this would imply that the mother treated her sons differently from her daughters or that the aberrant behavior of the mother had differential effects on the sons and daughters. Although both hypotheses are possible, there is little data to support either one. Other behavioral variables, such as early handling and isolation vs. group living are unlikely explanations because the males and females were subjected to the same experimental procedures in all four experiments.

The physiological variables, especially the androgens and neurotransmitters, offer some interesting possibilities. Variations in androgen levels have been shown to be related to aggression [2, 3, 5, 6, 25]. Interestingly, the normal development of the gonads has been shown to be adversely affected by low zinc concentrations in the rat [19–21] and human [27]. There are several studies [4, 8, 9, 23, 28, 29] that have found that the catecholamines, especially low levels of norepinephrine, were correlated with high levels of aggression. However, this hypothesis has been challenged [1]. In another study, it was found that the most aggressive female rats (ZD) had significantly lower concentrations of norepinephrine than normal female rats (AL) who had a normal level of aggression [24]. If these results are substantiated by further research, it would suggest that prenatal malnutrition, especially zinc deficiency, adversely affects one or more physiological mechanisms which then leads to higher levels of aggression.

Extrapolation from animal data to the humans is always hazardous and should be done with caution. Nevertheless, these experiments have shown that prenatal malnutrition does have adverse effects on the food consumption and weight gain of dams and their offspring and the subsequent aggressive tendencies of the offspring as young adults. It is known that severe maternal malnutrition can have an adverse effect on the growth of the human fetus and neonate but the consequences on the behavioral development of the human infant are still incompletely understood [30]. The findings in this study support the concept of postnatal behavioral deficits being induced by maternal malnutrition. They also suggest an area of human behavior which may warrant investigation as it is affected by nutrition in early life.

REFERENCES


