Effects of a program of human interaction and alterations in diet composition on activity of the hypothalamic-pituitary-adrenal axis in dogs housed in a public animal shelter

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Objective—To determine whether a program of human interaction or alterations in diet composition would alter activity of the hypothalamic-pituitary-adrenal (HPA) axis in dogs housed in an animal shelter.

Design—Prospective study.

Animals—40 dogs.

Procedure—Dogs were (n = 20) or were not (20) enrolled in a program of regular supplemental human interaction (20 min/d, 5 d/wk, for 8 weeks) involving stroking, massaging, and behavioral training. In addition, half the dogs in each group were fed a typical maintenance-type diet, and the other half were fed a premium diet. Plasma cortisol and ACTH concentrations were measured during weeks 0, 2, 4, and 8 and before and after exposure to a battery of novel situations during weeks 0 and 8.

Results—Plasma cortisol concentration was significantly decreased by week 2, but plasma ACTH concentration was not significantly decreased until week 8 and then only in dogs fed the premium diet. Following exposure to novel situations, plasma cortisol and ACTH concentrations were significantly increased. However, during week 8, dogs enrolled in the program of human interaction had significantly lower increases in cortisol concentration than did dogs not enrolled in the program.

Conclusions and Clinical Relevance—Results suggest that both a program of human interaction and alterations in diet composition have moderating effects on activity of the HPA axis in dogs housed in an animal shelter and that activity of the HPA axis may be increased for a longer period during shelter housing than measurement of plasma cortisol concentration alone would suggest. (*J Am Vet Med Assoc* 2002;221:65–71)

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Supported by a grant from the Iams Co.

The authors thank Franklynn Graves, Deborah Maken, Shonagh O'Leary, Heather Stewart, Lisa Pitstick, Jennifer Reed, and Barbara Freck for technical assistance and Stephanie Smith and the staff of the Montgomery County Animal Shelter, Dayton, Ohio, for their cooperation and support in conducting this research.

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Each year in the United States, millions of dogs are confined in public and private animal shelters.[1] Dogs often arrive at these shelters in a poor physical state because of injury, sickness, or malnutrition. Moreover, confinement in these shelters may be psychologically stressful, as the dogs are separated from attachment figures and exposed to novel situations and noises. In addition, the new environment is unpredictable, and the animals lose control over environmental contingencies. These are precisely the types of stressors that are known to activate physiologic stress systems, particularly the **hypothalamic-pituitary-adrenal (HPA)** axis, in dogs and other animals.[2-9] In fact, dogs have plasma cortisol concentrations during their first 3 days of confinement in a public animal shelter that are higher than concentrations in dogs that have been confined in the shelter for longer periods and concentrations in dogs maintained in their owners' homes.[10]

Methods that reduce activity of the HPA axis in dogs confined in a public animal shelter would, therefore, likely improve the welfare of dogs in these environments. Preliminary evidence suggests that human interaction involving soothing tactile contact and behavioral training may be a practical means to calm shelter dogs and help them adjust to an adoptive home.[11] In addition, soothing tactile contact immediately following venipuncture reduces the increase in plasma cortisol concentration associated with this mild stressor in shelter dogs.[12] However, it is not clear whether human contact would have a more general effect of either hastening adaptation of the HPA axis to the shelter environment or reducing the response of the HPA axis to a stressor experienced at a different time in a different context.

The emotional reactivity and behavior of dogs are thought to also be influenced by the specific content of their food, although there appears to be little consensus on the nature of this influence. It has been suggested that increasing the dietary protein content can calm excitable dogs and improve behavior under stressful circumstances.[13,14] In contrast, recent studies[15,16] have suggested a link between high protein diets and aggression in some dogs. Correcting acute nutritional deficiencies is an important consideration for the welfare of dogs admitted to shelters. However, it is unclear whether manipulating the content of diets that meet minimal standards would provide additional benefits.

The purpose of the study reported here, therefore, was to determine whether a program of human interaction or alterations in diet composition would alter activity of the HPA axis in dogs admitted to a public animal shelter. Effects of the experimental treatments on activity of the HPA axis during the initial 8 weeks of confinement in the shelter were assessed by measuring plasma cortisol and ACTH concentrations. In addition, to assess effects of the experimental treatments on activity of the HPA axis in response to an acute stressor, plasma cortisol and ACTH concentrations were measured before and after exposure to a combination of various novel elements (environment, person, moving object, and noise) shortly after admission to the shelter and again 8 weeks later.

Materials and Methods

Dogs—Twenty male and 20 female dogs admitted to the Montgomery County Animal Shelter in Dayton, Ohio, were used in the study. To be eligible for inclusion in the study, dogs had to be healthy, as determined by results of a standard complete physical examination performed by a veterinarian at the time of admission to the shelter. Furthermore, dogs had to be judged to be suitable candidates for adoption once the study had ended. This latter judgment was made on the basis of observations of the behavior of the dogs by shelter staff and project personnel. Dogs that exhibited aggression or obvious timidity were not entered into the study. The pool of potential subjects included stray dogs, dogs surrendered to the shelter by their owners for various reasons, and dogs seized by shelter staff because of neglect or other violations. Both sexually intact and gonadectomized males and females (nonlactating) were included. Thus, the sample approximated the population of dogs commonly available at shelters. To restrict the age range of subjects, dogs < 6 months of age, as judged by inspection of the dentition, were excluded from the study. Most dogs accepted into the study appeared to be between 6 months and 2 years old. Because of the difficulty of documenting the source of many dogs brought to the shelter, no attempt was made to distinguish subjects on the basis of provenance.

Upon admission to the shelter, eligible dogs were assigned to 1 of 4 experimental groups defined by factorial combination of 2 levels of human interaction and 2 diets. Assignment was made in a quasi-random fashion, with the following restrictions: each experimental group had to consist of 5 males and 5 females, and mean weights of dogs assigned to the 4 groups had to be roughly equivalent. Further, to provide some estimate of and balance in the phenotype of dogs assigned to each experimental group, a trained observer judged which of the 7 American Kennel Club breed groups each dog best fit, and to the extent possible given the other restrictions, dogs judged to be of the same breed group were distributed across experimental groups. The judgment of breed group represented a forced-choice procedure, because many of the dogs possessed characteristics of > 1 breed group.

During the course of the study, dogs were maintained in a dedicated room that was illuminated during daylight hours by a combination of artificial and natural lighting. The room contained a bank of metal cages of various sizes (0.6 to 0.9 × 0.7 × 0.6 to 0.7 m), as well as 2 larger pens (1.5 × 0.8 × 1.9 m). Dogs were kept in cages or pens according to body size. Potential subjects were not admitted to the study if a cage or pen of an appropriate size was not available at the time of shelter admission. So that conditions of the subjects mimicked typical conditions for shelter dogs, procedures related to how the dogs were housed, fed, and cared for were in accordance with shelter policy. As with the shelter population as a whole, dogs were sometimes removed from their cages for bathing, health inspection, or treatment. These removals were brief and infrequent and never occurred just prior to blood sample collection.

Experimental treatments—All procedures were approved by Wright State University's Laboratory Animal Care and Use Committee. Wright State University is fully accredited with the Association for Assessment and Accreditation of Laboratory Animal Care.

Experimental treatments were initiated on the dog's sixth day in the shelter. Thus, for this study, the first 5 days in the shelter were designated week 0, and day 6 marked the beginning of week 1 of the 8-week treatment period. Two experimental treatments were studied: effects of a program of human interaction and effects of feeding a premium diet versus feeding a standard diet. Regular supplemental periods of human interaction were provided in a small room (7.1 m^2) located 19.5 m from the housing area in the shelter. As described,[11] this room was referred to as a living room, because it was intended to simulate a room in a residential dwelling, such as a living room, to which the dogs were likely accustomed prior to admission to the shelter and to which they might be exposed following adoption. The room contained a desk and chair. Light was provided by a desk lamp, as well as by overhead fluorescent fixtures. The room was carpeted and contained a small rug. The room adjoined the public waiting room and, so, was much quieter than the animal housing area. Five days each week, dogs assigned to this experimental treatment were brought individually to the living room for 20 minutes during the afternoon.

During the first 3 minutes in the living room, the dog was allowed to explore freely. For the next 10 minutes, the dog was gently and slowly stroked and massaged while spoken to in a soothing manner.[12,17] During this time, the dog was restrained and encouraged to maintain body contact with the handler. For the last 7 minutes, the dog was trained to obey various commands by use of positive-reinforcement training techniques. Training began with simple tasks (eg, come, sit, lie down) and progressed through more difficult exercises (eg, remain seated while the handler left and reentered the room). During each training session, half a hot dog sliced into small pieces was used as positive reinforcement. Dogs not exposed to the living room were supplemented with half a hot dog 5 days a week. These hot dogs were the only supplement to the assigned diets provided to the study dogs.

Handlers for the program of human interaction were trained prior to participating in the study. This training involved all aspects of the handler's interactions with the dogs, including, for instance, the manner in which the dogs were stroked and massaged,[12] the handler's tone of voice in interacting with the dogs, the handler's positioning and posture in the room, and the manner in which commands were given and reinforcements were offered. To further ensure conformity during the study, handlers followed a systematic, detailed protocol for the program of human interaction. The identity and sex of the handlers were equated across groups to the extent possible given the various practical constraints of the study (eg, coordination of the study with the normal operations of the shelter, schedules of the students serving as handlers, and the need to enroll dogs in the study as they became available). Each dog was exposed to the same handler during at least 70% of its sessions in the living room. For each of the 2 groups assigned to the program of human interaction, 6 dogs were exposed predominantly to a male handler, and 4 dogs were exposed predominantly to a female handler.

All dogs in the study were given a 10-minute walk outdoors on lead, 5 days a week, for the duration of the study. Individuals involved with the study and shelter staff were instructed to minimize interactions with the dogs during walks, feeding, and cage cleaning. Nonetheless, all dogs received modest human interaction during these procedures, and dogs differed only in regard to whether they were exposed to the living room.

Beginning on their sixth day in the shelter, dogs were provided with 1 of 2 experimental diets. The diet that dogs were fed prior to this time varied, depending on the diet being fed by the animal shelter at that time, but was never 1 of the experimental diets. The diets were formulated to mimic commercially available diets and to correspond to industry categories of "popular" (diet A) and "premium" (diet B) diets **(Appendix)**.[18] Nutrient content of each diet was determined following procedures established by the Association of Official Analytical Chemists **(Table 1)**.[19] Digestibility coefficients were determined prior to the present study by feeding the diets to a panel of dogs in a closed colony; feces and urine were collected and analyzed following standard procedures. Both diets met or exceeded daily minimum nutrient requirements established by the Association of American Feed Control Officials[20] and were capable of fulfilling the basic nutritional needs of dogs. However, diet B provided greater nutritional quality than did diet A in terms of digestibility, percentage of animal-derived ingredients, and metabolizable energy. Diet B also contained more protein and fat.

All individuals involved with the study and shelter staff working with the dogs were blinded as to the identity of the 2 diets. National Research Council recommendations for estimating daily metabolizable energy requirements[21] were used to calculate the amount of food offered to each dog to maintain or achieve an ideal body weight and condition. Dogs that were obviously underweight at the time of admission to the shelter were fed rations suitable for their estimated ideal weight. At the time of each feeding, the amount of food remaining in the food bowl from the previous day was measured and recorded.

Blood samples for assessment of plasma cortisol and ACTH concentrations were collected on days 3 (week 0), 19 (week 2), 33 (week 4), and 60 (week 8). On days 3 and 60, additional blood samples were collected immediately after exposure to a combination of various novel elements so that each dog's response to this additional challenge could be evaluated. On these days, dogs were taken for a 10-minute walk after the initial blood sample had been collected. This walk terminated at a wooden building located in close proximity to the shelter. The dog was ushered into a 5.5 X 5.7-m test arena with concrete floor and wooden walls that had been constructed in the building and underwent a battery of tests designed to assess the behavior of shelter dogs under novel conditions.[22] Because the HPA axis is sensitive to novelty,[5] the test battery served as a stimulus for HPA activation. A second blood sample was collected immediately upon conclusion of the test battery.

Table 1—Nutrient content and digestibility of 2 diets used to examine the effect of diet composition on activity of the HPA axis in dogs housed in a public animal shelter

Variable	Diet A	Diet B
Protein (%)	23.0	29.9
Fat (%)	10.1	20.5
Moisture (%)	7.5	8.0
Crude fiber (%)	3.2	1.9
Carbohydrate (%)	47.2	32.2
Ash (%)	9.0	8.0
Calcium (%)	1.4	1.0
Phosphorus (%)	1.1	1.0
Metabolizable energy (Kcal/g)	3.3	3.9
Animal-derived ingredients (%)	25.7	53.6
Cereal-derived Ingredients (%)	72.8	36.6
Digestibility (%)		
Dry matter*	85.4	90.3
Organic matter*	88.5	92.8
Protein*	88.4	94.0
Fat*	89.4	94.5
Carbohydrate	90.5	91.2
Digestible energy*	88.6	93.5
Metabolizable energy*	84.9	90.3

*Value for diet B was significantly ($P < 0.001$) higher than value for diet A.

The test battery was divided into 4 phases. Briefly, in phase 1 (2 minutes), the dog was left alone in the arena. In phase 2 (3 minutes), a person who was unfamiliar to the dog entered and remained in the arena but did not interact with the dog. Following phase 2, the person left, and for the next 30 seconds, a remote-controlled toy car was made to repeatedly approach the dog. During phase 3 (2 minutes), the dog remained in the arena with the now stationary toy car. The beginning of phase 4 was signaled with the sound of an air horn and consisted of the dog remaining alone in the arena for an additional 2 minutes.

All blood samples (approx 1 ml) were obtained from the cephalic vein with a needle and syringe. One individual held the dog, and a second performed the venipuncture. The blood was rapidly transferred from the syringe to 2 tubes, 1 containing heparin for analysis of cortisol concentration and 1 containing EDTA for analysis of ACTH concentration. Samples were always collected within 4 minutes after the dog was removed from its cage or the test arena (mean ± SEM, 137 ± 4 seconds). Samples were placed on ice, and plasma was separated in a refrigerated centrifuge and frozen until analysis; samples for analysis of ACTH concentration were stored at –80 C.

Measurement of hormone concentrations—Samples for determination of cortisol and ACTH concentrations were assayed in duplicate with commercially available radioimmunoassay kits.[a,b] All samples were assayed at the conclusion of the study. Samples for analysis of ACTH concentration in 16 dogs (2 males and 2 females in each group) were lost because of assay error. These dogs represented random samples of the experimental groups, so their exclusion was not expected to introduce any bias in results for the remaining dogs. Intra-assay coefficients of variation were 7.6% for cortisol concentration and 20.9% for ACTH concentration. Interassay coefficients of variation were 18.0% for cortisol concentration and 9.6% for ACTH concentration.

Data analysis—Data were analyzed primarily with ANOVA procedures. For multilevel repeated-measures analyses, the Greenhouse-Geisser correction factor was used when sphericity was problematic, as indicated by the Mauchly test. Duncan multiple range tests were used for multiple paired comparisons. Three-way ANOVA with factors for the program of human interaction (yes vs no), diet (A vs B), and week of treatment (weeks) were used to analyze plasma cortisol and ACTH concentrations, with blood sample collection time treated as a repeated measure. Paired *t* tests were used to compare plasma cortisol and ACTH concentrations before and after exposure to the test battery of novel situations. Because subjects were a heterogeneous assortment of sexually intact and gonadectomized adult and prepubertal males and females and because equal numbers of males and females were included in each group, dogs of both sexes were combined for primary analyses. Pearson product moment correlation coefficients were used to assess the possible relationships between blood sample collection time and plasma cortisol and ACTH concentrations. For these correlations, a 1-tailed P value < 0.05 was considered significant. For all other comparisons, a 2-tailed P value < 0.05 was considered significant.

Results

Details of the amount of food consumed and changes in body weight will be reported elsewhere.[23] Briefly, nearly all the food provided was regularly

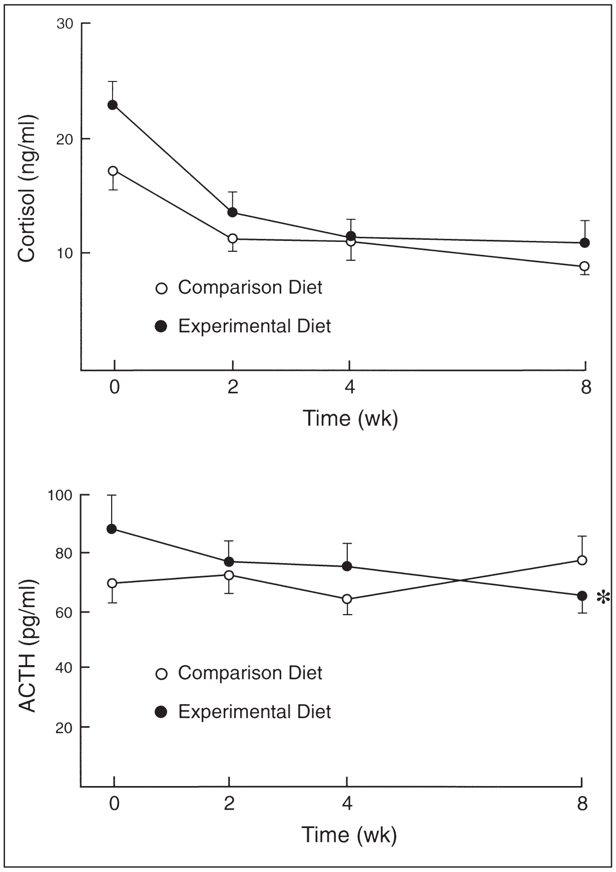

Figure 1—Mean plasma cortisol (top) and ACTH (bottom) concentrations in dogs housed in a public animal shelter for 8 weeks and fed a typical maintenance-type diet (comparison diet; n = 20) or a premium diet (experimental diet; 20). Error bars represent SEM. *Significantly ($P < 0.05$) different from week-0 value for that group.

eaten, particularly after the first few weeks. For dogs fed diet B, body weight at the end of the study (week 8; mean ± SD, 16.16 ± 5.46 kg [35.54 ± 12.02 lb]) was significantly greater than body weight at the beginning of the experimental treatments (week 0; 14.58 ± 5.03 kg [32.07 ± 11.07 lb]). For dogs fed diet A, body weight at the end of the study (16.73 ± 7.95 kg [36.80 ± 17.50 lb]) was not significantly different from body weight at the beginning of the experimental treatments (16.38 ± 7.67 kg [36.04 ± 16.88 lb]).

Week of treatment had a significant ($P < 0.001$) effect on plasma cortisol concentration, but the program of human interaction and diet did not **(Fig 1)**. Paired comparisons indicated that plasma cortisol concentrations during weeks 2, 4, and 8 were significantly ($P < 0.01$) lower than concentration during week 0. Analysis of plasma ACTH concentrations revealed a significant interaction between diet and week of treatment. Paired comparisons indicated that for dogs fed diet B (ie, the premium diet), plasma ACTH concentration during week 8 was significantly decreased, compared with concentration during week 0; however, concentrations during weeks 2 and 4 were not significantly different from concentration during week 0. For dogs fed diet A (ie, the popular diet), plasma ACTH concentration did not vary significantly during the study.

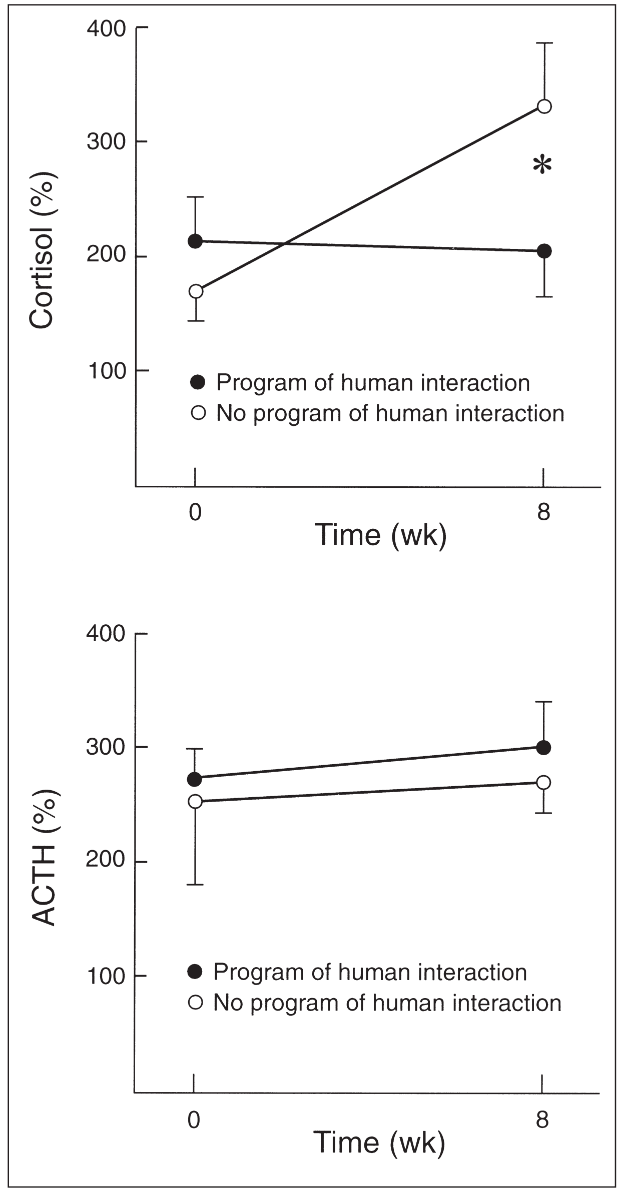

Figure 2—Mean plasma cortisol (top) and ACTH (bottom) concentrations in dogs housed in a public animal shelter that were (n = 20) or were not (20) exposed to a program of human interaction 5 d/wk beginning during week 1. Cortisol and ACTH concentrations were measured immediately after exposure to a battery of novel situations and are expressed as a percentage of concentrations immediately before exposure to the test battery. Error bars represent SEM. *Value for the dogs enrolled in the program of human interaction was significantly ($P < 0.05$) different from value for dogs that were not enrolled in the program.

To examine the effect of exposure to novel situations, we first determined whether plasma cortisol and ACTH concentrations after exposure to the test battery were significantly higher than concentrations before exposure. For both week 0 and week 8, significant differences were found. Subsequently, to determine whether the experimental treatments (ie, the program of human interaction and diet) affected the response to these novel situations, we analyzed plasma cortisol and ACTH concentrations after exposure to the test battery, expressed as a percentage of concentrations before exposure, with a 3-way ANOVA. For cortisol concentration, this analysis revealed that the main effects of diet and time were significant. Because the main effect of diet included concentrations measured before (week 0) and after (week 8) experimental treatments were instituted, results may be interpreted as reflecting a preexisting difference in the population of dogs assigned to the 2 diet groups, rather than as an effect of the dietary manipulation. The main effect of time was qualified by a significant interaction with the program of human interaction (**Fig 2**). The increase in plasma cortisol concentration in response to novel situations was almost twice as great during week 8 as during week 0 if dogs had not received the program of human interaction during the intervening period. However, for dogs that had received the program of human interaction, the increase in plasma cortisol concentration in response to novel situations was not significantly different during week 8 from the increase during week 0. For plasma ACTH concentration, there were no significant main or interaction effects.

To further examine the effects of the program of human interaction on the increase in plasma cortisol concentration in response to novel situations, additional post hoc assessments were conducted. Exploratory ANOVA including sex of the dog and sex of the primary handler as variables indicated that the effect of the program of human interaction was comparable for male and female dogs and for dogs handled primarily by males and those handled primarily by females. The effect of the program of human interaction on dogs of the various breed groups was also examined. Because of the small number of dogs in each of the various breed groups, no statistical analyses were performed, but visual inspection of the data revealed no obvious differences among breed groups in regard to effects of the program of human interaction.

Finally, to assess whether plasma cortisol and ACTH concentrations were affected by the time required to collect blood samples, we computed correlation coefficients for sample collection time versus cortisol or ACTH concentration for all subjects (40 for cortisol concentration; 24 for ACTH concentration). For this analysis, we chose a priori to examine plasma concentrations following exposure to the novel situations during week 0. No significant linear relationships between sample collection time and plasma cortisol or ACTH concentrations were detected.

Discussion

Results of the present study suggest that both a program of human interaction and alterations in diet composition have moderating effects on measures of activity of the HPA axis among dogs housed in a public animal shelter. Among dogs not exposed to the program of human interaction, the percentage increase in plasma cortisol concentration following exposure to novel situations nearly doubled from week 0 to week 8. In contrast, among dogs exposed to a modest amount of regular human interaction, the increase in plasma cortisol concentration following exposure to novel situations was the same during week 8 as during week 0. Thus, continuous housing in the shelter appeared to result in sensitization of the endocrine response to novel situations, but regular human interaction prevented this sensitization from occurring.

The program of human interaction did not have any effects on the change in plasma ACTH concentration in the present study. Because blood samples were collected at a single time after exposure to the novel situation, the lack of an effect on ACTH concentration may have been a result of differing time courses for ACTH and cortisol responses. Thus, without examination of samples collected at additional times, one cannot conclude that the program of human interaction affected only cortisol responses and not ACTH responses.

In the present study, dogs fed diet B (ie, the premium diet), which had a higher percentage of animal-derived ingredients, better digestibility, greater metabolizable energy, and higher protein and fat contents, had lower plasma ACTH concentrations during week 8, compared with week 0, whereas dogs fed the comparison diet (diet A) did not. Because dogs fed diet B had somewhat higher ACTH concentrations than did dogs fed diet A at the initiation of the treatment period, these results should be considered preliminary until replicated. Nonetheless, results suggest that diet may influence adaptation to the shelter environment. However, this effect was seen only for ACTH concentration. Plasma cortisol concentration decreased significantly by week 2 in both diet groups, without any apparent difference between groups.

Following short-term exposure to stress, secretagogues released from the hypothalamus, particularly corticotropin-releasing factor, stimulate the pituitary to release ACTH, which in turn causes the adrenal cortex to secrete glucocorticoids such as cortisol. Thus, responses of the various hormones of the HPA axis are typically highly correlated, although each follows its own particular time course. During long-term exposure to stress, this correlation can be reduced (ie, HPA axis dysregulation may occur) by, for instance, a gradual reduction in the sensitivity of a gland for its tropic hormone. In earlier work,[10] we observed a protracted stress response in dogs admitted to an animal shelter. Plasma cortisol concentrations were high during the first 3 days that dogs were in the shelter and gradually decreased thereafter. Similarly, in the present study, plasma cortisol concentrations, initially measured on day 3, decreased by the time they were next measured (day 19). However, plasma ACTH concentrations, which we had not measured in the previous study, did not change significantly during this period. These findings may suggest that with continual stimulation by ACTH, the sensitivity of the adrenal cortex diminished. If so, this would mean that activity of the HPA axis at the level of the pituitary, and possibly at the level of the brain, was elevated for a much longer period during shelter housing than observation of plasma cortisol concentrations alone would suggest.

In a recent study[22] examining possible predictors of behavior in dogs adopted from a shelter, we were surprised to find that relatively low cortisol concentrations on the second day in the shelter were associated with greater risk that adoptive owners would report behavioral problems 6 months following adoption. It

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was hypothesized that low cortisol concentrations in these dogs might not be a reflection of diminished stress in response to confinement in the shelter but, rather, might be an indication of dysregulation of the HPA axis as a result of exposure to stress prior to admittance to the shelter. For instance, dogs experiencing stress because of neglect or abandonment might have reduced sensitivity of the adrenal gland secondary to prolonged elevations of ACTH concentration. If so, admittance to the shelter might cause a smaller increase in plasma cortisol concentration in these dogs than in dogs not undergoing continuous exposure to stress prior to admittance, even if both groups of dogs secreted equivalent amounts of ACTH. The finding in the present study that plasma cortisol concentration had decreased significantly by week 2, whereas plasma ACTH concentration had not, suggests that dogs housed in animal shelters may indeed sometimes have reduced adrenal gland sensitivity in response to continuous psychologic stress and secretion of ACTH.

With the venipuncture procedure used, all blood samples were collected within 4 minutes, and most were collected much faster. Findings in rats and mice suggest that this is rapid enough to ensure the blood sampling procedure itself does not affect concentration of cortisol in the samples collected.[23-25] Plasma ACTH concentration increases more rapidly in response to stimulation than does plasma cortisol concentration; therefore, plasma ACTH concentrations in the present study probably were influenced to some degree by the sampling procedure. However, the lack of a significant correlation between ACTH concentration and sampling time indicates that any such effect was not substantial. Further, it is clear that changes in ACTH concentration reflected the experimental manipulations, as indicated both by the effect of diet and by the observed increase in ACTH concentration following exposure to novel situations.

Unusually high or low plasma concentrations of the hormones of the HPA axis (particularly plasma glucocorticoids in plasma and corticotropin-releasing factor in the hypothalamus and other brain regions) in humans are associated with a wide range of psychologic and bodily disorders, ranging from anxiety disorders and chronic fatigue syndrome to post-traumatic stress disorder and major depression.[26-29] Increasingly, response of the HPA axis to previous stressful events is being viewed as part of the etiology of such disorders.[27,30,31] Therefore, minimizing activity of the HPA axis during shelter housing may be valuable not only for the immediate welfare of the animal but, possibly, also for its future health and welfare.

In a previous study,[12] we demonstrated that human interaction involving soothing petting could moderate the increase in plasma cortisol concentration in response to the mild stress of venipuncture in shelter dogs when the petting immediately followed venipuncture. However, for the broad goal of diminishing the stressfulness of shelter housing, reducing activity of the HPA axis only at the time of the treatment itself is of limited value. For this reason, the present study was designed to determine whether human interaction or dietary alterations could produce more lasting effects. In this regard, the present findings extend the earlier results in 2 ways. First, they suggest that a program of human interaction at a time remote from acute exposure to psychologic stress can reduce the expected increase in cortisol concentration. This effect can be attributed specifically to the program of human interaction in the present study, because all dogs received modest human interaction associated with feeding, cage cleaning, and walking. Second, findings suggest that nutritional variables can independently reduce the increase in plasma ACTH concentration in response to shelter housing. In related work (unpublished), we also found that the behavior of dogs in an animal shelter can be affected by human interaction and diet, in that a program of human interaction and feeding a premium diet apparently had calming influences.

The present results also raise questions for future research. For instance, it is not clear which components of the complex behavioral and nutritional treatments are critical or whether results generalize to dogs in shelters with different housing conditions. Nevertheless, the present findings do suggest that offering a program of human interaction and feeding a high-quality diet may be practical means of reducing the impact of shelter housing on dogs and that these procedures warrant further research.

[a]Coat-a-Count, Diagnostic Products Corp, Los Angeles, Calif.
[b]RSL ^{125}IhACTH, ICN Biomedical, Costa Mesa, Calif.

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Appendix

Major ingredients (in decreasing order of content) in 2 diets used to examine the effect of diet composition on activity of the hypothalamic-pituitary-adrenal (HPA) axis in dogs housed in a public animal shelter

Diet A	Diet B
Ground corn	Chicken
Meat and bone meal	Ground corn
Wheat flour	Poultry fat
Soybean meal	Grain sorghum
Wheat midds	Brewer's rice
Corn gluten meal	Fish meal
Animal fat	Beet pulp
Flavor digest	Flavor digest
Sodium chloride	Dried egg
Calcium carbonate	Dicalcium phosphate
Dicalcium phosphate	Potassium chloride
Vitamins	Brewer's yeast
Minerals	Ground flax
	Sodium chloride
	Menhaden oil
	Magnesium sulfate
	Choline chloride
	Calcium carbonate
	DL-methionine
	Vitamins
	Minerals