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ABSTRACT

This paper reports an observational study of the effects of handling on the social behavior of squirrel monkeys who received a protein deficient diet. After birth, experimental animals received a low-protein diet for a 6-week period. A subgroup of these animals were handled between 3 and 12 weeks of age. All of the animals interacted (in four animal social groups), five times a week beginning at 4 weeks of age. Animals were observed interacting twice-weekly. Results indicate that protein deficiency produces a general retardation of development as measured by locomotion, use of space and social contact. Between 20 and 41 weeks most of the differences had disappeared; the differences that did maintain offer evidence that handling attenuates the effect of protein deficiency, specifically in the area of motor behavior and activity. It is suggested that low levels of protein in the diet during the critical period of brain development cannot be compensated for fully by handling. Loss of the non-handled deprived group by death leaves unanswered the question of persistent effects of handling on the ultimate outcome of nutritionally deprived animals. (GO)

SOCIAL BEHAVIOR IN INTERACTING SQUIRREL MONKEYS WITH DIFFERENTIAL NUTRITIONAL AND ENVIRONMENTAL HISTORIES

Patricia F. Chappell

Frankova's early finding that low levels of social contacts were characteristic of malnourished animals has been supported by studies of the effects of nutritional insult on social behavior across species. (Kerr & Waisman found retarded social behavior in malnourished rhesus monkeys; this was confirmed by Zimmerman, Steere, Strobel & Hom, who found low social responsiveness was characteristic of malnourished rhesus; Levitsky & Barnes found low levels of social contacts in malnourished rodents and Baldwin & Baldwin (1974) found during naturalistic observations of squirrel monkeys living under conditions of low supplies of food preferred by squirrel monkeys that no social play was observed during the 10 weeks of observation. Rather most of the troop's waking day was spent in foraging or travelling between food sources. Chavez et al found higher levels of social responsiveness in groups of human infants whose families had been supplemented with food than in infants whose families who had not been given food supplement). Frankova later hypothesized that addition of stimulation external to the malnourished animals would increase the level of social responsivity of the malnourished animals. She added stimulation by introducing a well-nourished "aunt" rodent to her malnourished mother with litter and found that social contacts did increase. We are reporting here another source of early stimulation--handling. Handling has served most frequently as a source of early stimulation with rodents but rarely if ever before as a source of early stimulation in primates, and as this report reflects, we believe we have made a very successful application of an old

treatment to modulate the effects of protein deficiency. Half of our animals reported on here , those reared with social experience, also received handling between 3 and 12 weeks of age for 5 minutes a day. All of the animals reported on here interacted 5 times a week beginning at 4 weeks of age for brief periods which were increased gradually to four hours a day. No report is made here of the animals reared in single cages. Beginning at 4 weeks and continuing until 20 weeks of age, observations were made of animals interacting in groups of 4, twice weekly. The observations were 10 min in length and behaviors which occurred during a 15 sec epoch were recorded at the sound of a tone. An observer recorded the behavior of one animal and worked either with another observer or from video tapes of the interactions. At 41 weeks of age, 33 weeks following the dietary deprivation period, a final set of observations were made of the three surviving groups. The fourth group, the non-handled protein-deficient group, consisted of one member by that time, the two male members dead from the effects of the dietary deprivation, one at 8 weeks and one at 25 weeks, and one female dead from a cage accident. The last observations of social behavior were made during the first and third 10 min of in teraction on two days in week 41; data were collapsed across both days and time periods in every case where appropriate statistically.

MEASURES

Spatio-Proximal Behaviors. The experimental space used to house the animals became the observational space and consisted of four cages and four playpen sectors, for a total of eight sectors which an animal could occupy each epoch. Animals could be either in cages or pen or both during any one epoch of observation. Occupation of a sector (regardless of length of stay)

was recorded; in addition, the degree of closeness of other animals was judged on a 4-point scale each epoch. Thus, for each 15 sec epoch, a record was made of the actual count and location of sectors the target animal occupied, as well as of its proximity to other animals. (Reliability for recording space occupied: 93% agreement.) Included in this report are measures of amount of time spent in two upper pen sectors and in the two lower-pen sectors, as well as measures of time spent in Proximity One--solitary occupation of a sector for the majority of an epoch, and Proximity Four--full body contact for the major portion of the epoch. (Reliability for proximity measures are for Proximity One, 91% agreement and for Proximity Four, 95% agreement). The unit of measurement is always the number of 15 sec epochs during the 10 min observation the behaviors occurred, except where otherwise specified.

Motor Behavior. Any locomotion of one half a body length or greater was recorded and all varieties of locomotion were recorded--walking, climbing, jumping, etc. Only climbing and jumping are reported here. Reliability for climbing was 94% agreement and for jumping, 72%.

Interchanges. Only two types of social interchanges are reported, wrestling and clinging. Wrestling involves full-body contact while rolling and grasping a partner, and is usually accompanied by mouthing or biting; by definition, it is reciprocal in nature. Clinging, on the other hand, is non-reciprocal by definition though it involves full-body contact between two animals. Dorsal-ventral positioning defines this behavior, with grasping of the recipient as its identifying component. (Reliability for wrestling was assessed at 94% agreement and for clinging at 97%).

ANALYSES

Each of the measures of the above defined behaviors was separately compared across diet and rearing conditions at 4, 8, 12, 16, and 20 weeks in

a 2 X 2 X 5 ANOVA with weeks as a repeated measure. At 41 weeks, Duncan's multiple range tests were used to compare group differences, and also to examine 3-way interactions in the ANOVA results; t-tests were used to examine 2-way interactions. All sources of differences among animals are given in the appendix with F values and P values.

RESULTS

Spatio-Proximal Behaviors

Use of space. Upper pen: A significant increase in time spent in the upper pen by weeks obtained--at 4 weeks, very little time was spent in the upper pen, but a steady increase occurred across weeks until, at 20 weeks, a mean 75% of time for all animals was spent in the upper sectors of the playpen. Both diet and rearing conditions produced a significant difference in the amount of time the animals spent in the upper pen, with protein-deficient animals there significantly less frequently except at 4 weeks (when no animals spent much time there) and at 20 weeks when no differences obtained. Non-handled animals also spent less time in upper pen sectors than did their handled counterparts, except at 4 weeks. At 41 weeks no differences obtained among the three groups of surviving animals.

Lower pen: Whereas amount of time all animals spent in lower pen differed significantly according to weeks and to diet condition, sub-group time in lower pen varied significantly with weeks. Non-handled control diet animals, in general, spent less time in the lower pen than any group and the handled protein-deficient animals spent significantly more time in the lower pen than other animals at 4 and 12 weeks. No differences obtained among groups at 8 weeks. Non-handled protein-deficient animals spent more time in the lower pen than non-handled controls but no more than handled controls at 16 weeks. At 20 weeks, handled protein-deficient animals spent

more time in the lower pen than handled controls. (At 8 weeks, protein deficient animals in both rearing conditions spent very little time in the pen at all, i.e., their time was spent in cages instead as would be expected at the end of the dietary deprivation. At 12 weeks, protein-deficient non-handled animals spent even less time in the pen, and the handled deficient animals more than doubled their time in the pen in contrast to their scores at 8 weeks. A similar increase in time in the pen is seen in the non-handled deficient animals, but at 16 weeks rather than at 12 weeks. However, the majority of this time is spent in the lower pen as contrasted to the handled protein-deficient animals whose increase in time in the pen at 12 weeks had been in both upper and lower pen.) At 41 weeks, the handled control group spent significantly less time in the lower sectors than either the non-handled control group or the handled protein-deficient group; the latter two groups did not differ in time in lower pen.

Proximity One: The amount of time the animals spent in a sector alone was high at the outset of social interaction, over 50% of the time; a statistically significant decrease obtained across weeks. Diet in interaction with rearing produced significant differences in proximity one scores. Non-handled protein-deficient animals spent more time alone than all other groups; handled protein-deficient animals spent more time alone than either control group, and handled controls more than non-handled controls. At 41 weeks, during the third 10 min of interaction, the handled protein-deficient group spent more time alone than its control group, but no more than the non-handled control group.

Proximity Four: Low levels of close body contact obtained at 4 weeks with gradual increases until 12 weeks; from 16 to 20 weeks, decreases in proximity four occurred. Diet and rearing conditions produced significant differences in regard to amount of time spent in close proximity. Examination of these effects showed non-handled controls spent more time in close body contact than any other group; handled controls spent more time in proximity four than handled protein-deficient animals, and non-handled protein-deficient animals more than handled protein-deficient animals. Rearing differences varied across weeks, with differences greater at 8 weeks and at 12 weeks but still significantly different at 16 and 20 weeks. At 41 weeks, non-handled controls spent significantly more time together than handled protein-deficient animals, but no more than the handled control group.

Motor Behavior

Climbing. Climbing scores changed significantly across weeks, beginning low at 4 weeks and increasing steadily until week 20. The two diet group differed significantly in amount of climbing with protein-deficient animals climbing less often than their controls. These differences maintained across weeks. Similarly, rearing groups differed significantly in amount of climbing, with handled animals climbing significantly more often than non-handled animals. Again, the differences maintained across weeks. No differentes obtained among the three surviving groups at 41 weeks.

Jumping. Similar patterns were found in jumping between diet groups and between rearing groups and across weeks. The same steady increase in jumping obtained across weeks, but a more striking difference was found between diet groups late in the monitoring period and less differentiation early. Differences at 41 weeks were found on measure, with both handled groups with high scores of jumping than the non-handled control group. The handled protein-deficient group also outjumped its control group.

Interchanges

Clinging. Clinging presents a uniquely difficult problem insofar as data analysis is concerned: by definition, it is non-reciprocal in that it precluded clinging in the recipient. Thus, inordinately high variance is an expected component of clinging scores. Even so, a significant diet main effect was found with the protein-deficient animals lower at every point than their controls in amount of clinging. Whereas neither rearing conditions alone or in interaction with diet conditions produced significant differences statistically, examination of sub-group differences show consistently high clinging scores in the non-handled control group. At 41 weeks, this group was clinging statistically more often than either of the handled groups.

Wrestling. Slow to appear, wrestling increased significantly over weeks. At 4 weeks, no differences obtained among groups; at 8 weeks, the handled control group wrestled significantly more often than all other groups, none of whom had been observed wrestling. At 12 weeks, the non-handled control group wrestled significantly more than both protein-deficient groups but no more than the handled control group. At 20 weeks, the non-handled control animals wrestled more often than all other animals. Parenthetically, no wrestling was recorded in the non-handled protein-deficient group at any point except at 16 weeks when the mean occurrence was less than 1 for a 10 min observation. At 41 weeks, significantly more wrestling was recorded for handled protein-deficient animals than their controls and more in non-handled controls than in handled controls. This held only for the third 10 min of interaction.

SUMMARY

Measures of proximity present a picture of more distance among the protein-deficient groups throughout the period of observation, with significant differences maintaining as long as 20 weeks in the non-handled protein-deficient group, and at 41 weeks, 33 weeks following protein deprivation in the surviving deficient group. An equally consistent finding was that handling served to differentiate between the two control groups in terms of distance among animals with a persistent effect of closer proximity in non-handled control animals, a difference which maintained until 20 weeks. Measures of use of space present an equally consistent picture of protein-deficient animals failing to move as freely about the experimental space as the control animals, a difference maintaining until 16 weeks. Measures of movement into

upper space indicate that protein-deficient animals failed to utilize this part of their environment at the rate and to the same degree that the control animals did. Here, handling expedited the movement into upper sectors. Confinement to lower levels of the playpen was characteristic of the protein-deficient animals far after the deprivation period, and an almost absenting of this area was characteristic of the handled control group.

Measures of locomotion revealed lower rates for protein-deficient animals--a difference maintaining until the end of the dietary deprivation and well beyond. Superiority in motor behavior performance was characteristic of the handled control group, a difference maintaining until 20 weeks.

Two measures of social interchange, wrestling and clinging, presented a picture of the non-handled protein-deficient animals almost completely lacking in these social interchanges. Either no, or very infrequent wrestling and clinging tended to characterize this group throughout. Handling again seemed to attenuate the diet effect in predicting more rapid development of social interchange, but non-handling in conjunction with control diet conditions predicted frequent clinging and wrestling which maintained until 20 and 41 weeks.

In sum, the results are consistent across most measures. Protein deficiency produced a general retardation of development, as shown in lower values on such measures as locomotion, use of space, and social contact. And though many differences disappeared by week 20 and most of them disappeared by 41 weeks, the differences that did maintain at

these points offer evidence that handling attenuates the effect of protein deficiency as well as expediting development in the non-malnourished animals, and in all probability--and from the evidence presented changing the nature of social interactions by altering such parameters of behavior as activity levels and motoric capabilities.

The significantly greater frequency of clinging and wrestling in the non-handled control group raises the question of the function of handling as an early supplement to social contact. From a comparison of the two control interacting groups, a picture emerges of non-handled animals maintaining a pattern of clinging and wrestling and close body contact throughout. Thus, on the one hand we can conclude that handling expedited development insofar as motor behavior and activity is concerned, whereas, on the other hand, it precluded in large part normal social contact which ordinarily provides stimulation and determines quite different patterns of social organization.

The general effect of protein-deficient regimes was to isolate the animals from social interchanges and to limit their movement throughout the experimental space. All evidence leads to the conclusion that low levels of protein in the diet during a critical period of brain development is an insult that cannot be compensated for easily. Handling modulates, in part, the effect of malnutriition, but even the handled deprived animals fail to maximally utilize their environment. The severity of the effect of malnutrition on behavior is demonstrated by the differences among groups which obtained on the measure, utilization of space, a dimension of behavior I feel represents, at least for this species, an index of survival. Not only does malnutrition result in less contact with the environment, in terms of the Levitsky-Barnes

speculation, in this case, nutritional status determined that part of the environment for which an animal was best suited, and that assignment, for this arboreal species, determined a low probability of survival almost from the outset. Unfortunately, the loss of the non-handled deprived group from the final analysis leaves in abeyance the question of the persistent effects of handling on the ultimate outcome of the nutritionally deprived animals.

SOURCE	F Value	df	P Value
SPATIO-PROXIMAL BEHAVIORS			
Time in Upper Pen			
Diet	18.16	1/24	< 0.001
Rearing	46.73	1/24	< 0.001
Weeks	41.55	4/96	< 0.001
Diet × Weeks	2.86	4/96	0.03
Rearing × Weeks	2.73	4/96	0.03
At 41 weeks*	N.S.	----	----
Time in Lower Pen			
Diet	14.95	1/24	0.001
Rearing	N.S.	----	-----
Weeks	2.58	4/96	0.04
Diet × Rearing × Weeks	4.09	4/96	0.005
At 41 weeks*	6.94	2/47	0.001
Proximity One			
Diet	42.46	1/24	< 0.001
Rearing	N.S.	----	-----
Diet × Rearing	6.09	1.24	0.02
Weeks	18.85	4/96	<.0.001
At 41 weeks*	5.33	2/23	0.001
Proximity Four			
Diet	36.35	1/24	0.001
Rearing	24.47	1/24	0.001
Diet × Rearing	13.12	1/24	0.002
Weeks	5.16	4/96	0.001
Rearing × Weeks	3.94	4/96	0.006
At 41 weeks*	2.86	2/23	0.10
MOTOR BEHAVIOR			
Climbing			
Diet	7.96	1/24	0.01
Rearing	16.50	1/24	< 0.001
Weeks	25.10	4/96	< 0.001
At 41 weeks*			
Jumping			
Diet	22.96	1/24	< 0.001
Rearing	9.55	1/24	0.006
Weeks	15.82	4/96	< 0.001
At 41 weeks*	50.34	2/47	0.001

INTERCHANGES

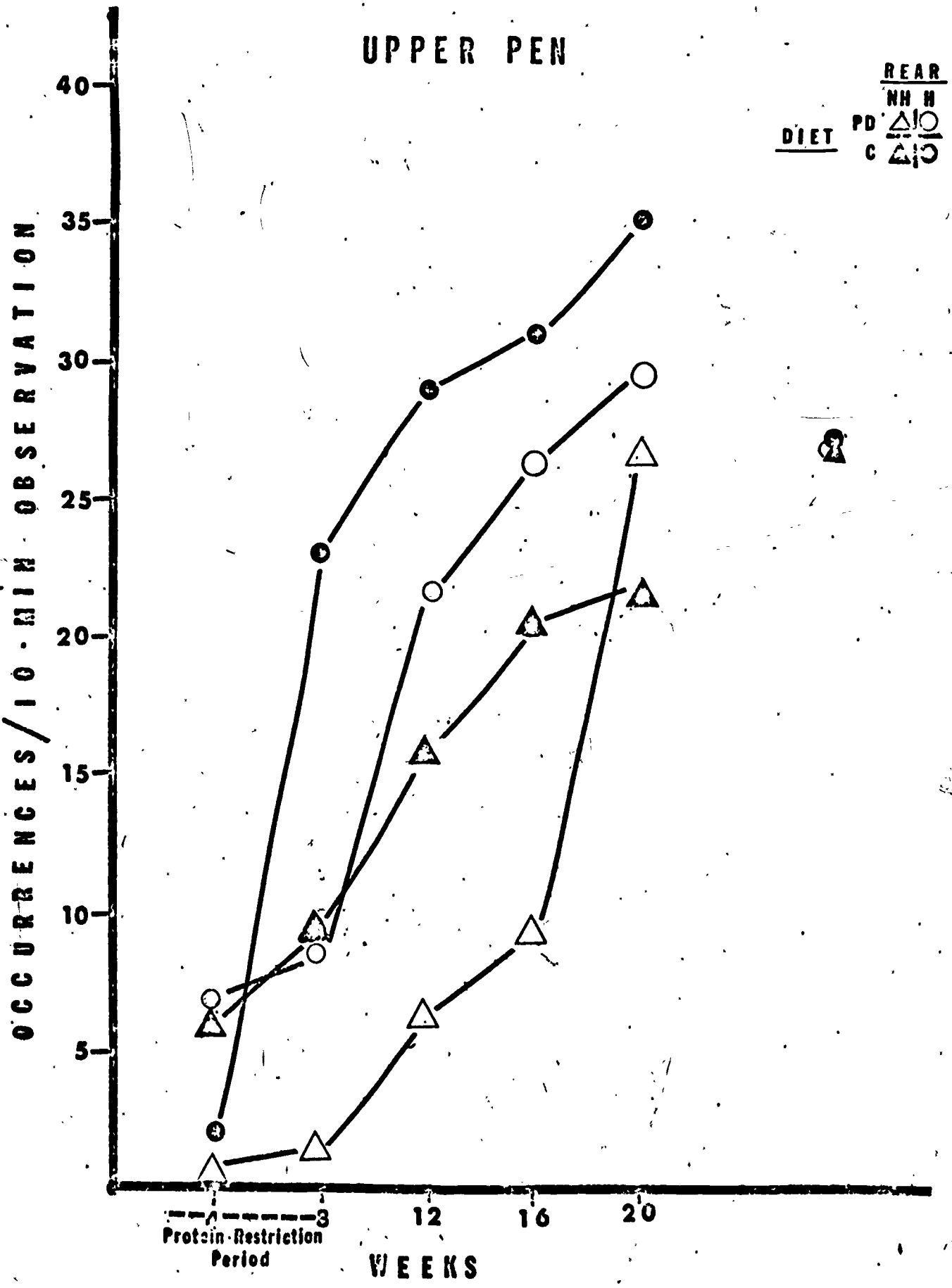
Clinging

Diet	4.67	1.24	0.04
Rearing	N.S.	----	----
Weeks	N.S.	----	----
At 41 weeks*	5.03	2/47	0.001

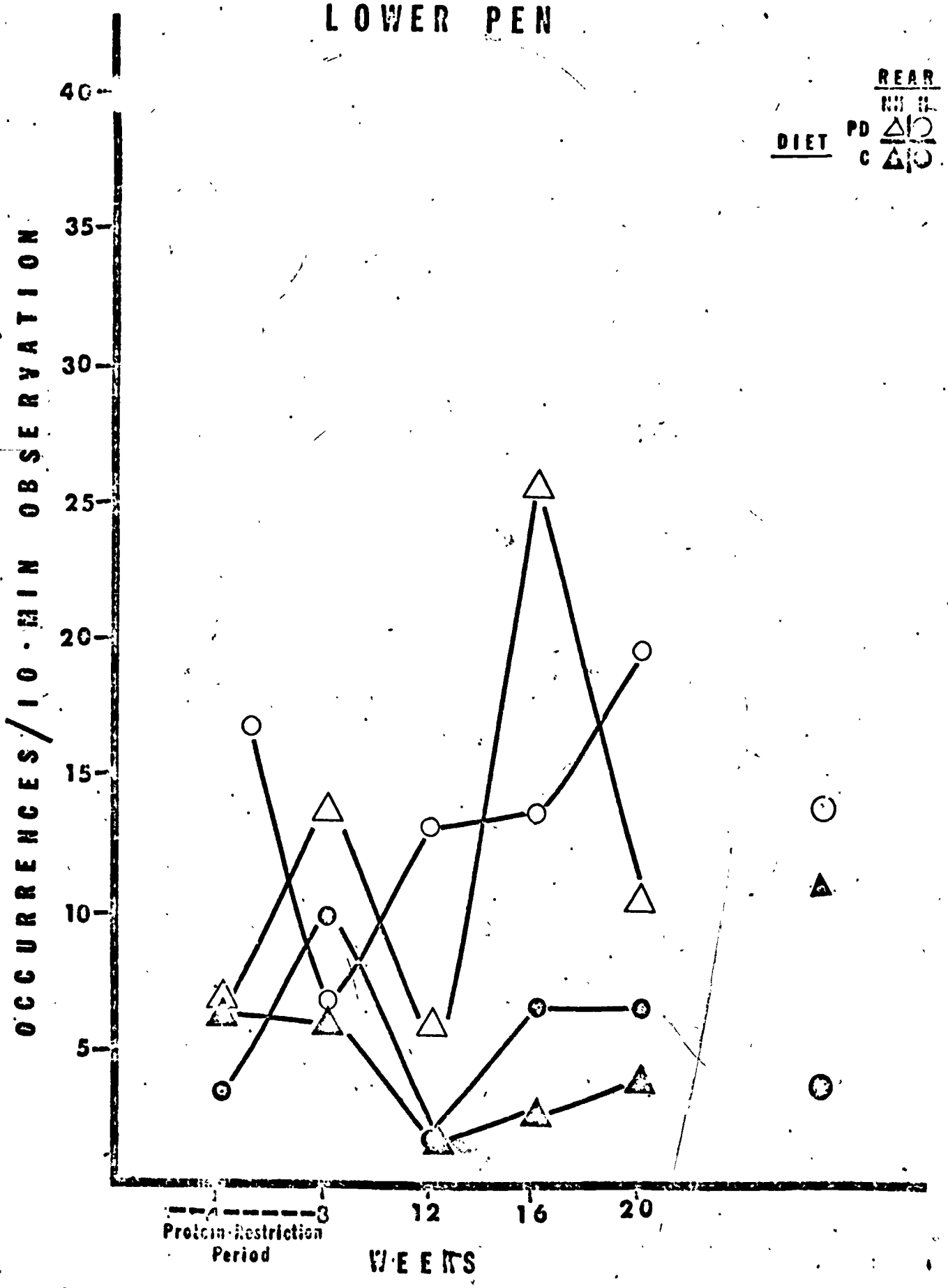
Wrestling

Diet	15.76	1/24	0.001
Rearing	N.S.	----	----
Diet × Rearing	10.95	1/24	0.003
Weeks	13.56	4/96	< 0.001
Diet × Weeks	5.11	4/96	0.001
Rearing × Weeks	3.45	4/96	0.01
Diet × Rearing × Weeks	9.40	4/96	< 0.001
At 41 weeks*	3.02	2/23	0.05

*Duncan's multiple range tests were used at 41 weeks to compare means of the three surviving groups: the handled and non-handled control groups and the handled protein-deficient groups.

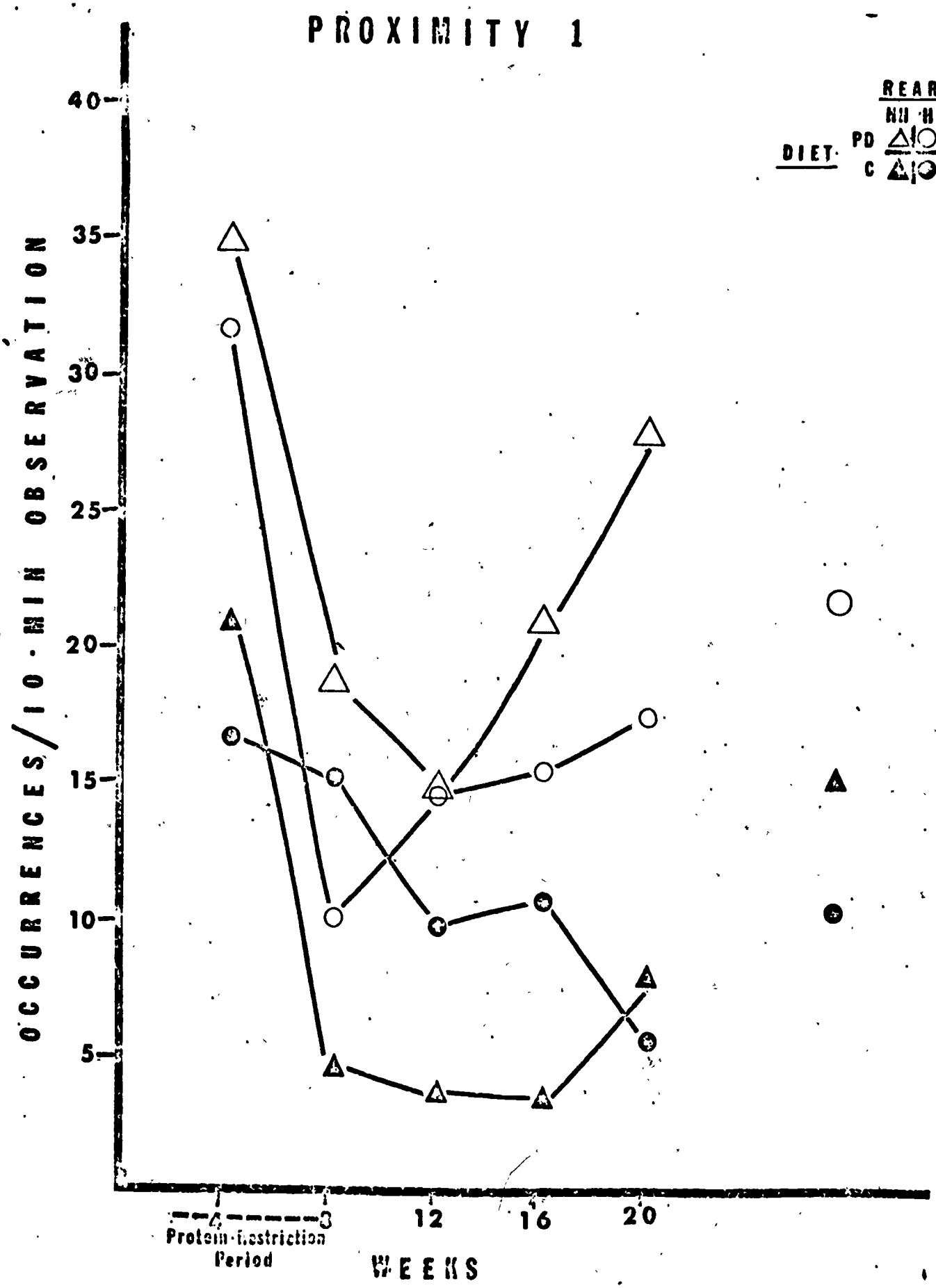


DIET X REARING



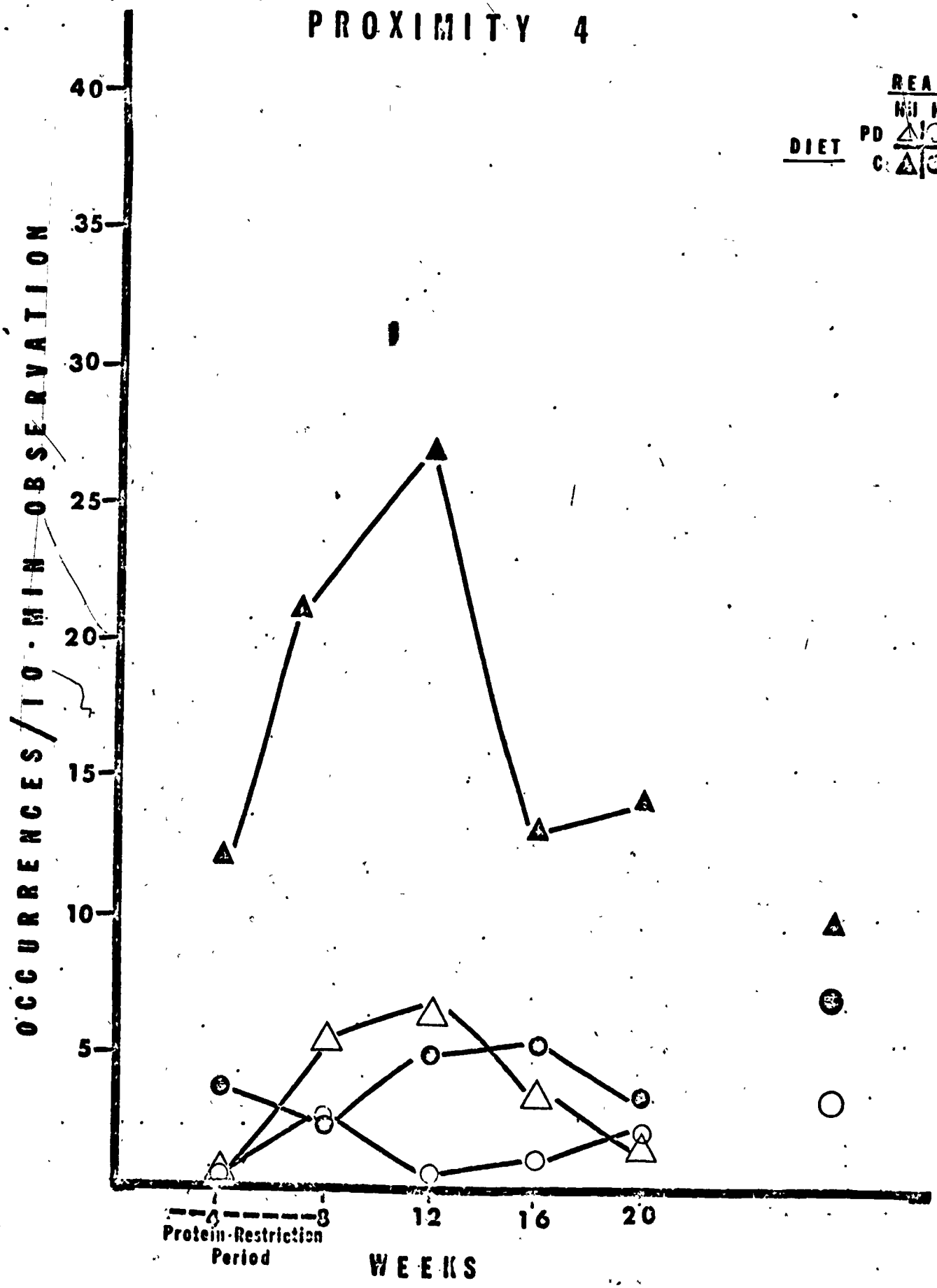
DIET X REARING

PROXIMITY 1



DIET X REARING

PROXIMITY 4



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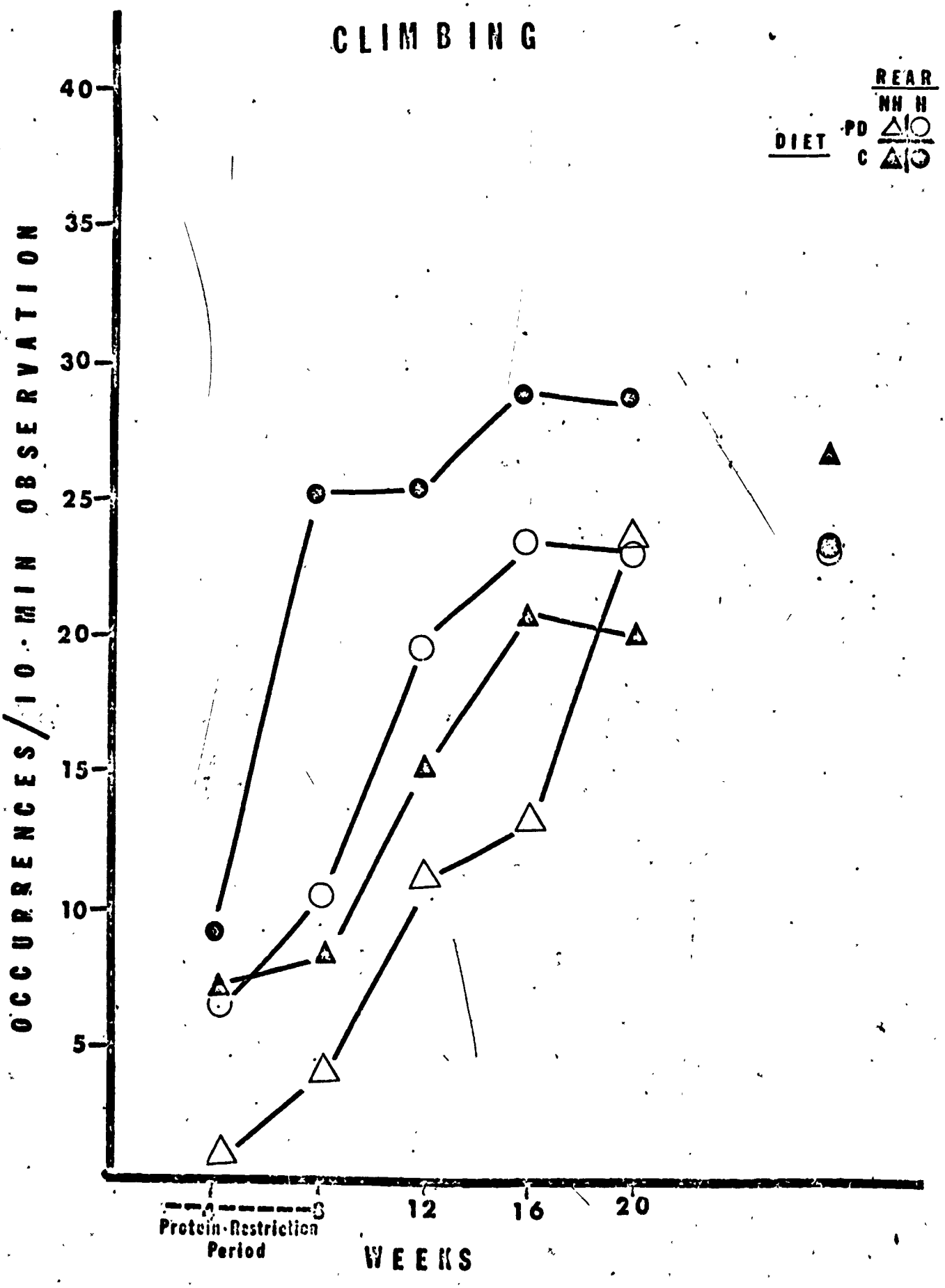

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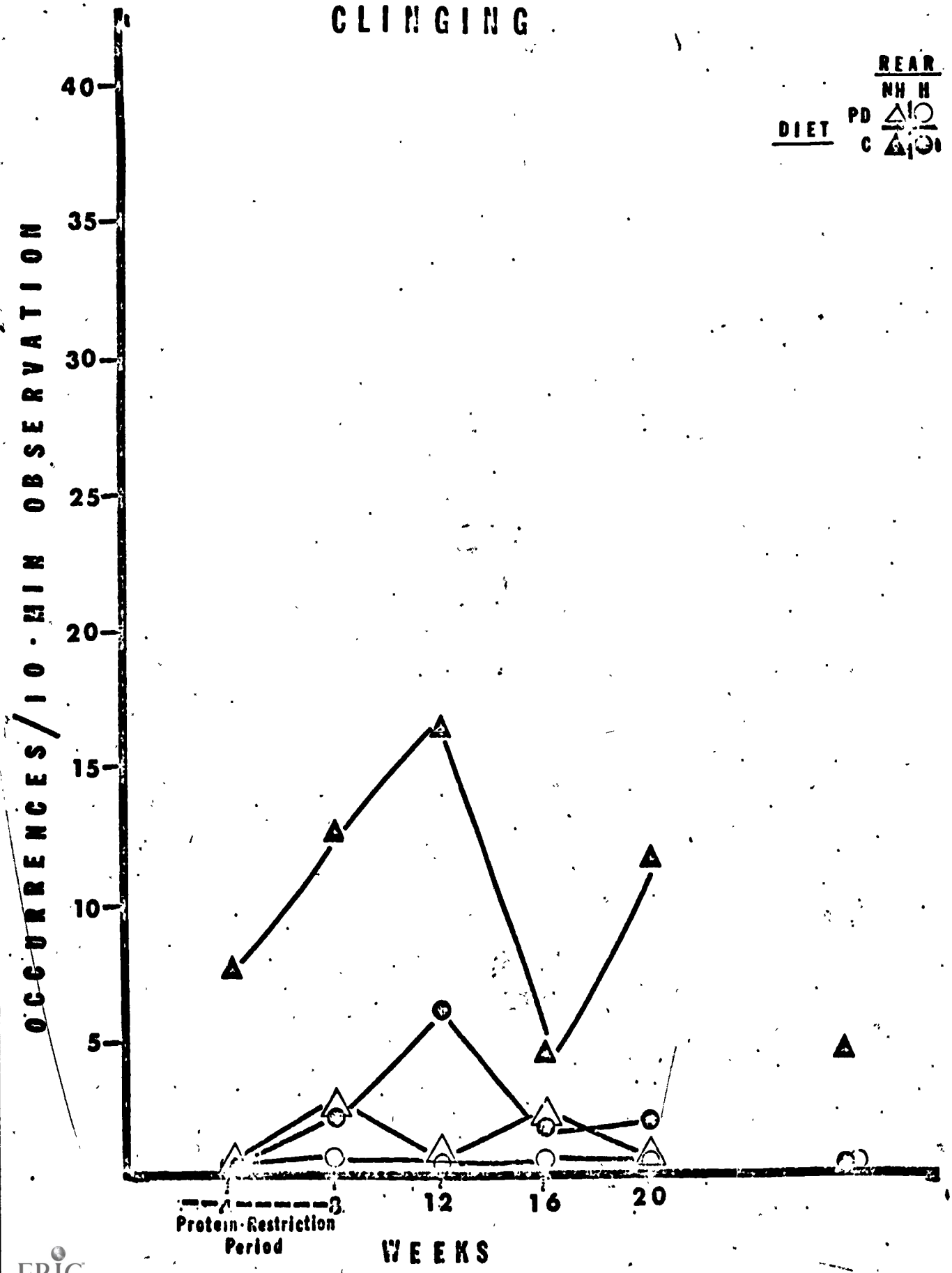
CLINGING
REAR
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40
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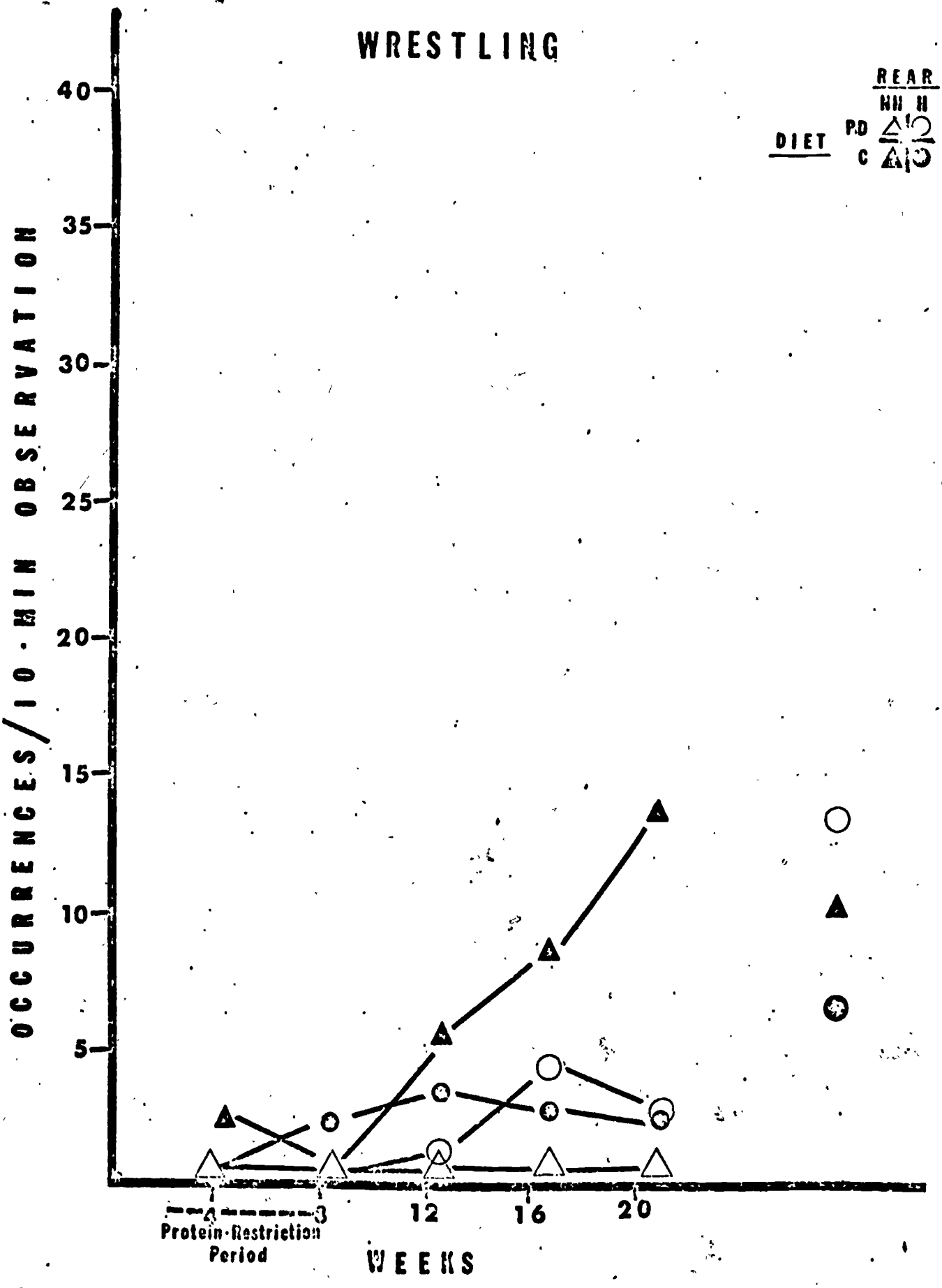
OCCURRENCES/10-MIN OBSERVATION
3
12
16
20
Protein-Restriction Period
WEEKS



DIET X REARING