Food, Sanitation, and the Socioeconomic Determinants of Child Growth in Colombia

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Abstract: To describe the causes of growth failure in a developing country, we studied family food availability, anthropometric measurements of preschool children, and family and neighborhood socioeconomic conditions in a stratified random sample of Cali, Colombia families. The influences on preschool child growth of food availability, neighborhood socioeconomic conditions, and family socioeconomic conditions were separated statistically. Neither food availability nor other family factors were related directly to growth, but neighborhood factors did have a strong relationship to growth. Children decreased progressively from 97.5 per cent of expected weight in the top one-sixth of neighborhoods we studied to 89 per cent in the bottom one-sixth. Food availability, although not related to growth, was strongly related to family factors. The top one-sixth of families had 115 per cent of FAO (Food and Agricultural Organization) protein allowances, while the bottom one-sixth had only 75 per cent. These findings are inconsistent with food availability or family factors being the principal causes of growth retardation. They are consistent with neighborhood determined factors, possibly enteric infections, being the principal cause of growth retardation in preschool children in Cali. (*Am J Public Health* 1981; 71:31-37.)

Introduction

Preschool child growth in developing countries has been related to socioeconomic conditions[1-7], although not consistently.[8] The socioeconomic effects could be mediated by food availability, by maternal care patterns, or by infection frequency and severity.[9-14] We have approached the evaluation of the relative effects of these different factors indirectly. We first separated the socioeconomic factors into family and neighborhood factors, then examined the independent associations between growth, food availability, family and neighborhood factors. We controlled the relationship between growth measurements and neighborhood factors for food availability and family factors by covariance analysis. We were motivated to take this approach by our deductions that enteric infection risks should be related neighborhood factors.[15,16]

Materials and Methods

Population Sample and Scaling Procedures

The 228 "barrios" (independent neighborhoods of 1,000 to 8,000 population) of Cali, Colombia, were scored on socioeconomic and environmental factors as previously described.[17] Fifty neighborhood factors which in some way reflected livability, hygiene, or socioeconomic status were recorded on each barrio. Data on some of these factors were ascertained from census records but data on most were obtained from a "windshield" survey. The barrios were then ranked as to livability by weighting the various responses to the 50 variables in a fashion so as to maximize the common source of variance that underlies these 50 variables. The technique used is called PRIDIT analysis (Principal Component Analysis on RIDITS).[17] This analysis showed that a subset of 18 variables accomplished the ranking most efficiently and that little was added by the others. Once the barrios were ranked, we divided them into seven strata with approximately equal populations. We decided not to select families from the top strata for interview because we wanted to make numerous direct observations in the home and we felt this would be resisted by the more elite population. One-half of the barrios from the bottom six strata were randomly selected and the blocks in these enumerated for random selection of 100 blocks per strata. The houses in each selected block were enumerated and randomly ordered. Visits were made to the houses in the random order and the first house encountered with children under age six was selected for induction into the study. From each of the bottom six strata, 100 families with preschool children were randomly selected for study. Eighty-five per cent of the eligible families agreed to participate. Those not agreeing to participate were evenly distributed across the strata. Replacements were sought in subsequent randomly ordered houses when the first eligible family could not be inducted into the study.

Once inducted, the families received numerous visits as part of the studies to be reported later. In the first visit, in

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August and September of 1977, 50 hygienic conditions and possessions of the family reflecting economic well-being were directly observed and recorded. Using the same PRIDIT technique as for the neighborhood scale, we found that 26 of these variables explained most of the variance. PRIDIT scores from these 26 variables were used to rank families into six approximately equal family strata as was done with the barrios. Thus, each family falls into one of six neighborhood and six family strata with about 100 families in each stratum. The lower numbers represent the higher strata.

Nutrition Data

The fourth visit was conducted by nutritionists not previously in contact with the families. Due to restricted availability of these interviewers, only 486 families could be visited. Approximately 75 homes were approached in which the interview was either refused or no one appropriate to interview could be found, and 39 homes were not approached. There were 557 children measured in the homes interviewed by the nutritionists: 76 under one year of age, 85 one year of age, 72 age two, 104 age three, 103 age five, and 117 five years of age.

The following information was obtained on each food available to the family:

a) length of purchasing cycle (daily, weekly, monthly, etc.)

b) the amount of food involved in the cycle (pounds, etc.)

c) the amount of money expended per food per cycle.

There were 120 different foods encountered in the households. The money measure was found more accurate than other units for certain kinds of foods and was used to calculate food volumes by employing the price in the market where the food was purchased. The number of calories and protein available to the family in these foods was calculated as follows:

Calories available per family per day =

$$\sum_{i=1}^{120} \frac{(\text{cal/g})_i \times g_i}{\text{days}_i}$$

Protein available per family per day =

$$\sum_{i=1}^{120} \frac{(\text{Prot/g})_i \times g_i}{\text{days}_i}$$

Where:

- i = A particular food
- $(\text{cal/g})_i$ = Calories per gram of food "i" using the Colombian food tables (18)
- $(\text{Prot/g})_i$ = Protein per gram of food "i" using the Colombian food tables (18)
- g_i = Quantity of food "i" available per cycle in grams
- days_i = length of the purchasing cycle for food "i" in days

In order to compare calories and protein intake between families, a relation expressing adequacy of nutrient intake with respect to the WHO/FAO (World Health Organization/Food and Agricultural Organization) standard[19] was calculated. To calculate the family allowance, each individual in the family was assigned the allowance corresponding to his particular status (i.e., pregnant, lactating, preschool child, school child, or adult). These allowances were then summed across all family members.

Growth Measurements

The growth of children under age six was evaluated by comparing actual growth and body proportions with the Colombian reference[20] by month of age and sex using the following relations: actual weight ÷ standard weight for age, actual height ÷ standard height for age, actual weight ÷ standard weight for actual height. The Colombian standards are generally below the Harvard standards with increasing differences after age two. All measurements were carried out with minimal clothing. Previous studies have standardized and minimized variation between the nutritionists and their assistants making the measurements.[21] Birth dates were obtained by two separate observers and confirmed with records when possible.

Statistical Analysis

Statistical analysis involved making scales to reflect the underlying source of variance to the family and the barrio level variables using the PRIDIT technique.[17] A combined scale added the sextiles of these PRIDIT scales and redivided the total into new sextiles. For subsequent analysis we used the Michigan Interactive Data Analysis Programs.[22] The means of anthropometric and food availability measurements at the sextiles of one scale were adjusted for the effects of the other scale or other factors through covariance analysis. Significance of trends was tested in multiple regression models.

Results

Table 1 shows some of the levels of some of the variables contributing to the neighborhood scale. The percentages do not always progress linearly because no one variable defines the scale, and all the variables do not vary together. Each variable had several levels and we have only selected here some levels in order to give the reader a feel for the kind of population we are dealing with at each of the sextiles in the final scale. For example, one can note that only in the bottom sextile were there barrios without treated municipal water being generally available. On the other hand, only in the upper third was it common to find barrios with the majority of the streets being paved.

Various levels of selected variables contributing to the family scale and the distribution of families with different characteristics by sextile are shown in Table 2. Again, we have selected variables for the purpose of illustration and to give an image of the types of family at each level. One can appreciate the role of hygienic, economic, and educational variables to the family scale. Table 2 shows that Cali is not an extremely poor area; sewage disposal and water supply is good by Latin American standards. The largest variation in sanitary conditions occurs at the poorest end of the scale.

TABLE 1—Neighborhood Scale Characteristics: Percentage of Families in Each Sextile of the Neighborhood Scale Who Live in Barrios with Various Characteristics

Neighborhood Characteristics	Sextile 1	Sextile 2	Sextile 3	Sextile 4	Sextile 5	Sextile 6
	%	%	%	%	%	%
1) Per capita average income, less than 6000 pesos	24	13	49	62	87	100
2) Average land value less than 250 pesos per M^2	4	8	24	79	77	100
3) History of flooding	46	39	73	67	91	81
4) Stagnant water persistently present	0	67	26	28	17	61
5) High crime rate	79	91	97	96	100	98
6) Presence of narrow unpaved streets	38	84	67	88	100	100
7) Majority of streets paved	96	67	0	8	0	0
8) Treated municipal water generally available	99	100	100	100	100	72
9) Municipal garbage collection service	99	100	86	51	80	41
10) Taxi service available during day	100	100	77	96	34	37
11) Taxi service available at night	97	100	54	45	31	28
12) Taxi service available during rain	99	100	53	33	4	15
13) Center at least ten blocks from main thoroughfare	17	47	0	0	11	58
14) Center within 15 minutes of clinic	89	57	38	57	1	41
15) Center within 20 minutes of hospital emergency room	92	84	83	81	69	71
16) Has a park	46	78	36	21	14	19
17) Center within 5 minutes of a fire station	49	9	9	0	0	0
18) Lending agency classifies as acceptable risk	99	85	95	66	69	87
19) Majority of homes are brick with good floors	82	58	65	41	67	0

Family classifications by neighborhood and family scales were correlated. Nonetheless, there was enough variation for our statistical techniques to separate the influence of the two scales on our outcome measures.

The average growth measures observed in Cali were below the standard of upper class Bogota children to which they were compared. The average height was 97.7 per cent of expected; the average weight per height was 98.5 per cent of expected; and the average weight was 94.3 per cent of expected. The weight and height deficits increased progressively with age, with most of the drop occurring before age three as seen in Table 3. The weight pattern by age seems to follow the height pattern per age with little weight per height deficit. Thus, we appear to be dealing with a cumulative height deficit without much evidence of acute wasting and with the major effect before age three.

The relationships of anthropometric measurements on children under age six to the overall socioeconomic scale are presented in Figure 1. The weight and height relationships are strong and highly statistically significant. There is evidence of a relationship to weight per height also, but this being a less marked deficit in our population, the relationship is not statistically significant. The relationships of weight and height to socioeconomic conditions are in the same direction in all age groups, but by far the strongest effects are seen in the two- to three-year-old age range as illustrated in Table 4. The weight per height relationship is less consistent with a trend toward reversal once height has been reduced in the older age groups.

The relationships of the nutrient availability measures to the overall socioeconomic scale are also strong (Figure 2). As one might expect, protein availability varied more than

TABLE 2—Family Scale Characteristics: Per cent of Families in Each Sextile of the Family Scale with Indicated Characteristics

Family Characteristics	Sextile 1	Sextile 2	Sextile 3	Sextile 4	Sextile 5	Sextile 6
	%	%	%	%	%	%
1) 3 or more water spouts in the house	97	90	84	67	35	7
2) No water spouts in the house	0	0	0	3	13	32
3) Water spout in the bathroom	78	31	18	8	3	0
4) Hand washing sink present	92	78	52	20	7	1
5) Soap observed in washing area	92	69	51	18	18	6
6) Towel observed in washing area	88	56	43	97	2	1
7) Hot water heater present	16	1	2	2	0	0
8) Shower present	100	100	92	88	76	26
9) Flushing toilet present	99	100	96	90	70	30
10) Toilet with lid present	78	32	23	17	4	0
11) Commercial toilet paper used	100	99	94	92	92	68
12) Independent kitchen area	98	96	98	89	89	61
13) Tiled kitchen floor	96	89	69	47	25	9
14) Cupboard for plates used	62	25	19	18	19	5
15) Complete set of plates for family	99	94	90	84	69	39
16) Refrigerator present	90	72	44	28	18	7
17) Kitchen sink present	100	99	93	76	36	10

calorie availability. None of the measures of nutrient availability were significantly related to the growth measures.

In Figures 3 through 6, we present the results of the covariance analysis separating the associations of the family and neighborhood scales to the outcome variables. Figure 3 indicates that almost all the socioeconomic variation in calorie availability is accounted for by the family scale. The same is true for protein availability (Figure 4). This is as one might expect because food purchase is largely a family level decision. Within Cali, there is little geographic variation in the market availability of foods to influence that family level decision.

TABLE 3—Per Cent of Expected Weight and Height per Age and Weight per Height by Age Group

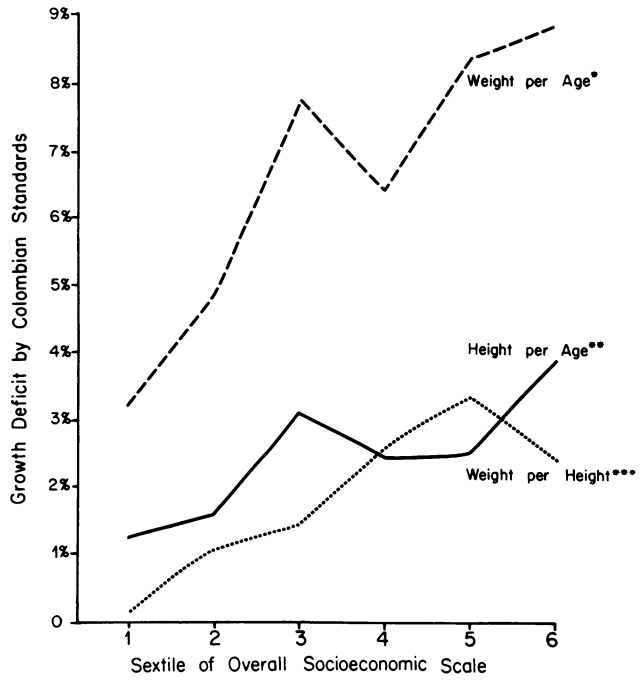
Age (years)	Weight per Age	Height per Age	Weight per Height
	%	%	%
Less than one	101	101	102
One	96	99	99
Two	93	97	98
Three	92	97	98
Four	93	97	98
Five	91	97	97

If family food availability were the primary determinant of growth in the under age six population, or if the separations seen in Figures 3 and 4 were an artifact of scale formation, one might expect the same separation in family and neighborhood effects as was observed for family food availability. This is clearly not the case. For weight and height (Figures 5 and 6), the neighborhood effects are strong and highly significant while the family effects are negligible. Our acute growth deficit measure (weight for height) showed less consistent variation by all measures of socioeconomic status, and thus the effects of the two separate types of factors are not separable for weight per height.

Discussion

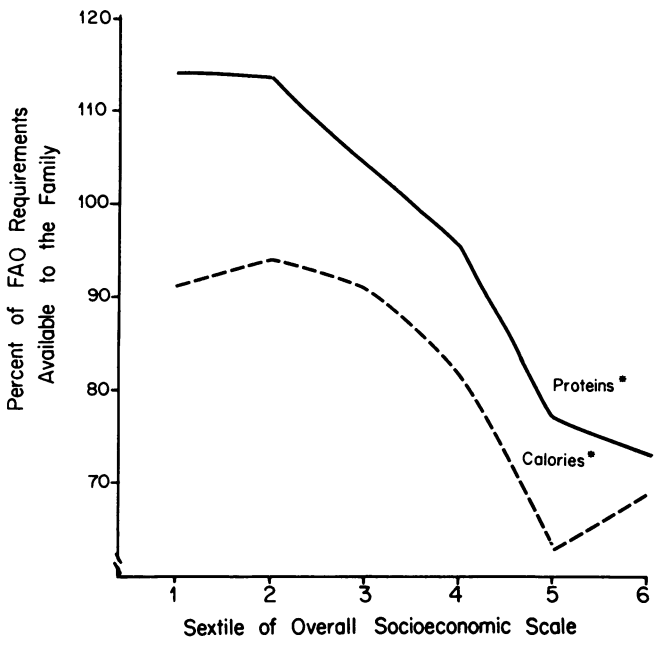
Current opinion holds that preschool child growth retardation results from interaction and vicious circles between infection and food availability. The two factors are so tightly linked that in most cases they cannot be separated. The neighborhood-family separation was suggested by consideration of enteric agent transmissions.[15,16]

Person-to-person transmissible enteric agents are so highly transmissible within families that almost no inter-



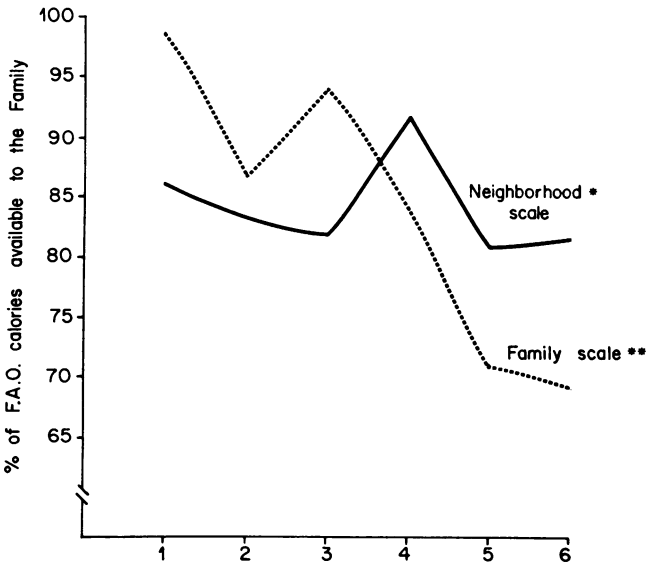
*Increase significant at p<.0001
**Increase significant at p<.0005
***Increase significant at .05<p<.1

FIGURE 1—Anthropometric Measures of Mean Growth Deficits by Sextile of an Overall Measure of Socioeconomic Status



*Decrease significant at p<.00001

FIGURE 2—Calorie and Protein Availability for Consumption by Sextile of an Overall Socioeconomic Scale



* Probability of observed variation occurring by chance >.5

** Decrease in calorie availability significant at p<.003

FIGURE 3—The Effects of Neighborhood and Family Factors on Family Calorie Availability

vention can stop this process; the incidence of infection with these agents will thus not be related to family factors. A public health intervention that reduces introduction into the family, on the other hand, stops the family chain of transmission before it starts. The inevitable family chains of transmission from neighborhood factors mean that person-to-person transmitted enteric agents will be related to neighborhood factors.

Since enteric infections are prominent causes of growth failure,[23-29] one would expect growth failure associated with these infections to be independently correlated with neighborhood rather than family factors. The amount of food available to a child, on the other hand, should be associated with family rather than neighborhood factors. This association is confirmed in our data in Figures 3 and 4. Our measure of food availability is a measure of food available to the family and may not precisely reflect the amount of food offered the child. The amount of food offered a child will be a function not only of food availability at the family level, but of maternal care patterns, family structure, and the health of the child which leads him to demand food. The first two fac-

TABLE 4—Regression Coefficients of the Neighborhood Scale on Anthropometric Indices by Age

	Anthropometric Indices		
Age (years)	% Expected Weight per Age	% Expected Height per Age	% Expected Weight per Height
Less than one	−.0188	−.0043	−.0057
One	−.0049	−.0017	−.0028
Two	−.0341	−.0133	−.0144
Three	−.0081	−.0047	−.0014
Four	−.0035	−.0057	+.0047
Five	−.0073	−.0052	+.0001

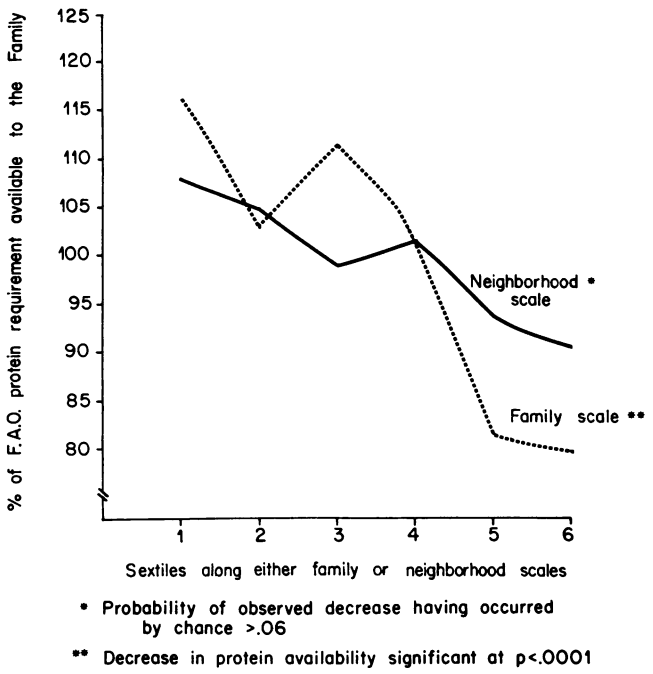


FIGURE 4—The Effects of Neighborhood and Family Factors on Family Protein Availability

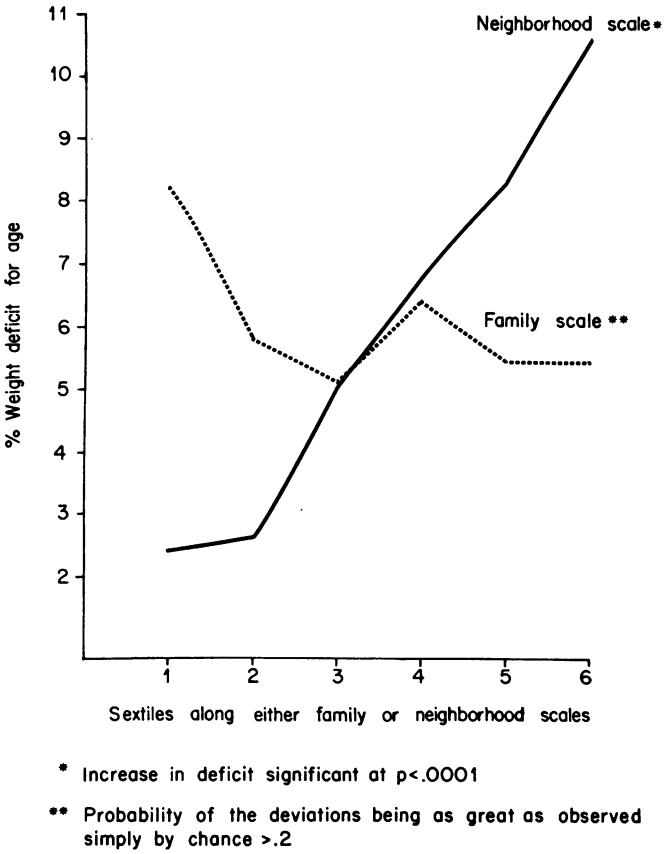


FIGURE 5—The Effects of Neighborhood and Family Factors on Weight per age in Cali Preschool Children

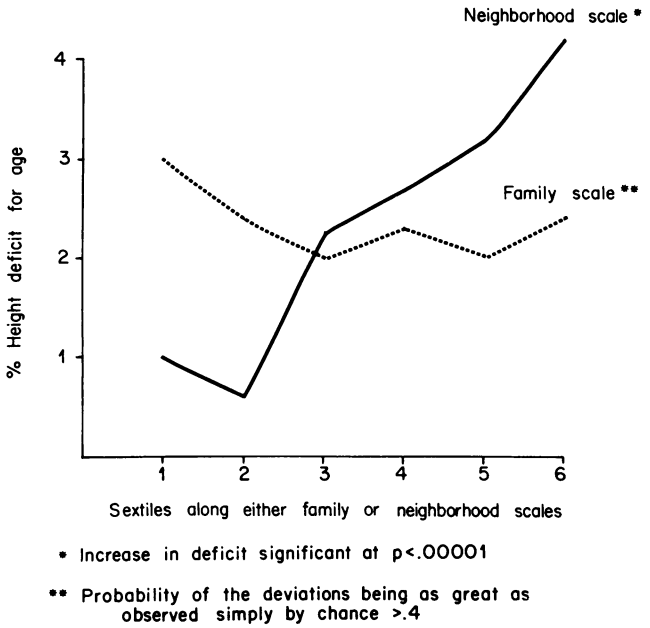


FIGURE 6—The Effects of Neighborhood and Family Factors on Height for Age in Cali Preschool Children

tors should vary with our family scale rather than our neighborhood scale.

If family food availability were the major determinant of growth in Cali preschool children, we should see the same relationships of growth to family and neighborhood factors that we saw for food availability. Our anthropometric measurements are very revealing in this regard. They reflect growth deficits by social class consistent with other studies done in the region.[6,30,31] Yet we failed to find a relationship between family factors or food availability and growth deficits.

When some nutritionists fail to find significant relationships between food consumption and anthropometric measures, they argue that the relationship must exist, but that inconsistencies in measurement obscure it. Our measures were consistent enough to get nice separation on the family and neighborhood scales but were not related to anthropometric measures. If the amount of food actually offered a child does determine the growth deficits we observed, that amount of food could not be determined by maternal characteristics which vary with our family scale. Any variance in the amount of food offered to a child could be a function of his anorexia. However, the growth deficits may not be due to anorexia. They could result from increased catabolism or malabsorption associated with infection.

Our data provide no direct confirmation that infection is the major cause of the neighborhood scale effect we observed. The infection data we were able to collect dealt only with intestinal parasites, and these are probably not the major infections affecting nutritional status. The infections causing acute diarrhea are likely to be more important.[23–26] Although we feel that enteric infection is the most logical explanation, medical care availability or some other factor might also explain the neighborhood scale effect. The pre-

dominance of the neighborhood over the family conditions in determining anthropometric measurements is, however, undeniable in our data. The major effect of neighborhood factors in the two-year-olds adds weight to the infection hypothesis and we feel that hypothesis to be most plausible.

The concept that infection with enteric agents whose incidence is a function of neighborhood factors is the primary determinant growth in Cali does not necessarily contradict the current wisdom that nutrition programs need to be focused directly on the most high risk infants. Within the traditional scope of nutrition programs, one of the most important aspects may be to maintain nutrition in the face of infection.[32] This might best be done by focusing directly on the high risk child, since such a child is the one who is most likely to suffer severe nutritional effects from infection.[33]

If our findings are not in conflict with the current focus on high risk infants, they certainly suggest a need to expand the attack on malnutrition with programs intended to control the transmission of enteric agents at a neighborhood level. The diarrhea surveillance system established in Cali[15] with the many fruitful disease control programs it stimulated[34–36] is an example of one method to control neighborhood disease transmission factors.

REFERENCES

1. Cunningham N: The underfives clinic—does it make a difference. J of Trop Ped Env Child Hlth 1978; 24:237-334.
2. Bouterline YH: Socioeconomic factors in child development. Malnutrition is a problem of ecology. Bibl Nutr Diet 1970; 14:43-63.
3. Cravioto J, Birch HG, deLicardie ER, Rosales L: The ecology of infant weight gain in a pre-industrial society. Acta Paed Scand 1967; 57:71-84.
4. Rea JN: Social and economic influences on the growth of preschool children in Lagos. Human Biol 1971: 43:46-63.
5. Graham GG: Environmental factors affecting the growth of children. Am J Clin Nutr 1972; 25:1184-1188.
6. Christiansen N, Mora JO, Herrera MG: Family social characteristics related to physical growth of young children. Brit J Prev Soc Med 1975; 29:121-130.
7. Desai P, Slandard KL, Miall WE: Socioeconomic and cultural influences on child growth in rural Jamaica. J Biosoc Sci 1970; 2:133-143.
8. Taylor CA, Amanuel I, Morris LN, Prosterman RL: Child nutrition and mortality in rural Philippines: Is socioeconomic status important? J of Trop Ped Env Child Hlth 1978; 24:80-86.
9. Monckeberg F: Factors conditioning malnutrition in Latin America, with special reference to Chile. Advices for a volunteers action. Bibl Nutr Diet 1970; 14:23-33.
10. Cravioto J: Complexity of factor involved in protein-calorie malnutrition. Bibl Nutr Diet 1970; 14:7-22.
11. Mukherjee DK, Sethna NJ: The ecology of growth in underprivileged children. Inaian Ped 1972; 9:440-446.
12. Beisel WR: Magnitude of the host nutritional responses to infection. Am J Clin Nutr 1977; 30:1236-1247.
13. Gordon JE: Epidemiological insights on malnutrition: some resurrected, others restructured, a few retired. Am J Clin Nutr 1978; 31:2339-2351.
14. Morley D, Bicknell J, Woodland M: Factors influencing the growth and nutritional status of infants and young children in a Nigerian village. Trans Roy Soc Trop Med Hyg 1968; 62:164-199.
15. Koopman JS, Guzman N, Henao O, Bergonzoli G: A diarrheal disease surveillance system in Cali, Colombia: Theoretical basis and methods. Bull Pan Am Hlth Organ 1978; 12:323-334.
16. Koopman JS: Causal models and sources of interaction. Am J Epid 1977; 106:439-444.
17. Bertrand WE, Brockett PL, Levine A: A Methodology of determining high risk components in urban environments. Intl J Epid 1979; 8:161-166.
18. Instituto Colombiano de Bienestar Familiar, Tabla de composicion de Alimentos Colombianos; fourth edition, Bogota, Colombia, 1978.
19. WHO technical report series #552. Protein and energy requirements, Geneva Switzerland, 1973.
20. Rueda-Williamson R, Luna Jaspe H, Ariza J, *et al:* Estudio seccional de crecimiento y desarrollo y nutricion de 12; 138 ninos de Bogota: Tablas de peso y talla. Rev Pediat 1969; 10:335-348.
21. Acciari G, Eckroad JC, Fajardo LF, *et al:* Comparative analysis of some anthropometric measurements. Archivos Latinoamericanos de Nutr 1978; 17:359-375.
22. Fox DJ and Guire KE: Documentation for MIDAS, third edition, Ann Arbor, MI, 1976
23. Mata LJ, Kronmal RA, Urrutia JJ, Garcia B: Effect of infection on food intake and the nutritional state: perspectives as viewed from the village. Am J Clin Nutr 1977; 30:1215-1227.
24. Martorell R, Habicht JP, Yarbrough C, *et al:* Acute morbidity and physical growth in rural Guatemalan children. Am J Dis Child 1975; 129:1296-1301.
25. Rowland MGM, Cole TJ, Whitehead RG: A quantitative study into the role of infection in determining nutritional status in Gambian village children. Br J Nutr 1977; 37:441-450.
26. Cole TJ, Parkin JM: Infection and its effect on the growth of young children: A comparison of the Gambia and Uganda. Trans Roy Soc Trop Med Hyg 1977; 71:196-198.
27. Azurin JC, Dizon JJ, Sullesta E, *et al:* A positive effect on the nutrition of Philippine children of an oral glucose-electrolyte solution given at home for the treatment of diarrhoea. Report of a field trial by an international study group. Bull WHO 1977; 55:87-94.
28. Martorell R, Yarbrough C, Lechtig A, *et al:* Diarrheal diseases and growth retardation in preschool Guatemalan children. J Phys Anthrop 1975; 43:341-346.
29. Rowland MGM, McCollum JPK: Malnutrition and gastorenteritis in the Gambia. Trans Roy Soc Trop Med Hyg 1977; 71:199-203.
30. McKay H, Sinisteria L, McKay A, *et al:* Improving cognitive ability in chronically deprived children. Science 1978; 200(4339):270-278.
31. Drake WD, Fajardo LF: The promotora program in Candelaria: A Colombian attempt to control malnutrition and disease, 1968-1974. Community Systems Foundation, Cali, Colombia, 1976.
32. Rohde JE: Preparing for the next round: Convalescent care after acute infection. Am J Clin Nutr 1978; 31:2258-2268.
33. Mata LJ: The children of Santa Maria Canque: A prospective field study of health and growth. Cambridge MA: MIT Press, 1978.
34. Koopman JS: Diarrhea and school toilet hygiene in Cali, Colombia. Am J Epid 1978; 107:412-420.
35. Koopman JS: The investigation of related cases for the control of diarrhea in cities in developing countries. Am J Trop Med Hyg 1979; 28:396-400.
36. Koopman JS: Eliminacion de aguas negras, suministro de agua y diarrea endemica en un barrio pobre. Bol Oficin Sanit Panamer LXXXVIII 1980; 5:402-412.

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