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Effects of Components of Sanitation on Nutritional Status: Findings from South Indian Settlements

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Hebert J R (Department of Nutrition, Harvard School of Public Health, 665 Huntington Avenue, Boston, MA 02115, USA). Effects of components of sanitation on nutritional status: findings from South Indian settlements. *International Journal of Epidemiology* 1985, **14**: 143–152.
The provision of sanitary facilities to a community neither guarantees they will be used nor that they will provide health benefits if they are used. This study, conducted in three urban communities in Madras, India, follows pre-school children over the course of approximately one year to determine the relative effects on growth of sanitation factors. These factors were defined as being under the control of children, those controlled by parents, and factors not under the direct discretionary control of any family member. Data were also collected on other variables suspected to affect nutritional or health status. A statistical technique was used that accounts for the effects of non sanitation-related variables. Children from 18 to 36 months of age benefit most from their own and their parents sanitary behaviour. Older children benefit from availability of resources for hygiene. Children under 18 months of age tend to be unaffected by any of the sanitation-related variables considered.

The purpose of this paper is to assess the roles, in terms of children's nutritional status, of three types of sanitation-related factors: those under children's direct control; those under parent's direct control; and those not under the direct control of any member of the household.

The study was conducted from November 1978 to January 1980 in three urban communities in Madras, India. The communities were chosen for their homogeneity for factors that are known to affect nutritional status. Measurements were made on the children and on household variables in three different seasons.

The importance of sanitation in improving health status has long been assumed in the developed countries.[1,2] Dramatic decreases in mortality and morbidity which were associated with improvements in sanitation in Europe and North America came at a time when means for sophisticated statistical analyses were unavailable. In developing countries, where funds for any programme related to health are severely limited, knowing whether sanitary behaviour is relatively more important than provision of sanitary facilities would be very useful. Despite a recognized need for more precise evaluation to demonstrate connections between sanitation and health,[3] there have been very few studies conducted to test the relative influence of various aspects of sanitation.

Sanitation-related variables may be divided into two broad categories: those that are under a person's direct discretionary control, and those that are essentially not under direct control. Where or how one chooses to wash or defaecate would be examples of the former category, whereas the existence of a plumbing system or latrine would be an example of the latter. If one considers children in particular, then a third category exists: variables that are under the direct discretionary control of parents but not of children. Factors related to parents' personal hygiene and household sanitation variables such as clothes washing would be examples of this third category.

One of the predominant problems in determining the effect of particular factors on the health status of a population, or a certain subgroup within a population, is the difficulty in accounting for other factors which are also known to affect the outcome.[4] It is well-known that there is a strong relationship between the level of economic development and the level of sanitary service standards[5] as well as a strong relationship between income and nutritional status.[6]

Most of the research that has looked into the effect of sanitary facilities on human health have employed models which oversimplify the relationships among the variable determining health status,[7] exclude information on variables that are known to be related

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to health status[8] and/or rely simply on control at the level of 'community' in the absence of any model.[9] In this study, information was collected on numerous social, economic, food-related and other environmental variables.[10] Those variables found to be important determinants of nutritional status in exploratory analysis are included here.

A second problem concerns the choice of outcome variable. Usually, the subgroup of interest within the population consists of children in the pre-school age range. This group tends to be the most vulnerable to sanitation-related diseases and also has a very high mortality rate.[11-13] For this group various morbidity surveys have been conducted.[1,14] Disease definition,[15-17] recall bias,[18] and incomplete reporting[8,19] have all been methodological problems. Recently, there has been increased use of anthropometric indices as a proxy for health status.[20,21] Anthropometric measurements can be extremely precise and accurate when performed properly and they can easily be compared to local reference values or to international reference values that are familiar to a wide audience.

Anthropometric indices have been used for various public health and medical purposes with increasing frequency since it was first observed that they correlated well with morbidity[22] and could be used to describe or predict risk.[23] By the middle of the twentieth century various reference series of child growth data had been compiled. The series used for comparative purposes in this paper are the WHO recommended NCHS/CDC reference series collected during the 1970's on US children.[24]

The tendency of children from well-nourished, affluent groups in the less developed countries and immigrants to the developed countries to approximate the growth of the NCHS/CDC reference group argues strongly against the importance of genetic determinants of growth.[27,28] It should be noted, however, that there are regional and ethnic differenes in growth within India.[29] Tamil people tend to be smaller than the national average,[30] though it is not clear whether the genetic potential to grow is any different. In addition, these reference values are used only for internal comparisons within a genetically homogeneous group.

A second objection to the use of anthropometry is that body size may not correlate well with health or nutritional status. Although it is recognized that large size is not necessarily a desirable condition, numerous studies have shown that children who do poorly in terms of illness or nutrition over short periods of time may be light for their height or length.[31,32] Children who have many acute episodes or protracted periods of illness or food deprivation may be stunted (have low height or length for their age).[33,34] Poor diet may make a child prone to illness;[35,36] an ill child can suffer nutritionally through food wastage,[37,38] metabolic losses[39] or anorexia.[40] Insufficient dietary calories and/or protein or diversion of nutrients due to illness can, in turn, cause deviations of growth from what would otherwise be expected.

METHODS

The study was conducted in Madras, the capital of Tamil Nadu state in Sóuth India (Figure 1). Madras is located on the Bay of Bengal, approximately 12.8 degrees north of the equator and is the fourth largest city in India. Many communities in the city are caste homogeneous. Hindu caste, or socio-religious status, is a powerful determinant of ritual and social behaviour. Caste identity may reflect a near uniformity in food choice, hygiene behaviour and occupation. To minimize the variability of caste-related behaviour, communities were chosen that were predominantly (> 95 per cent) from the Pattinavar caste. Approximately 50% of the heads of the households were engaged in the traditional occupation of fishing. Unlike many urban settlements, these communities were believed to be moderately stable. Relatively little

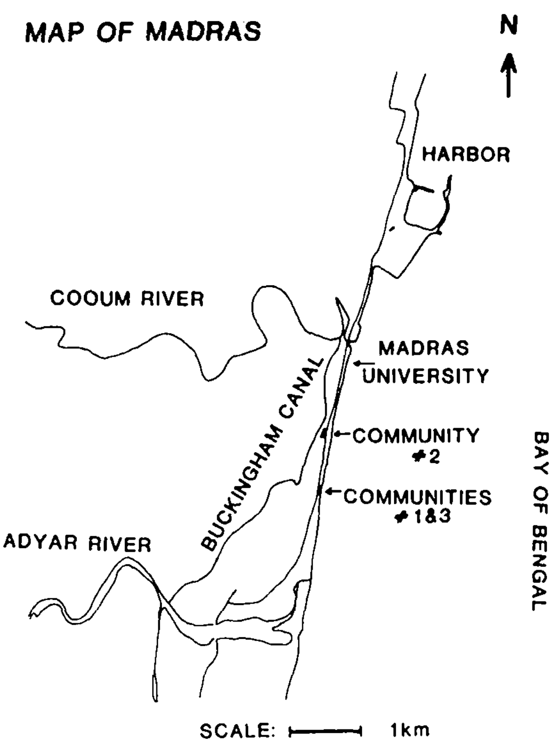

FIGURE 1

migration was thought to occur. Fishing, practised in traditional catamaran boats with nets, required intimate knowledge of the local coast and markets.

Two of the areas were composed of tenement housing which had replaced traditional stick and mud huts. These buildings were three or four stories high, and were made of concrete. Each unit contained approximately 500 square feet of living area. The buildings were about ten years old and were administered by the Tamil Nadu Slum Clearance Board.

The third community was adjacent to the first (Figure 2). It was composed mainly of traditional huts built of mud and sticks, although there were a few multi-storey homes of finished rock and plaster.

Washing and Faecal Disposal Facilities

All of the tenement housing was provided with overhead tanks for water storage, water piping to taps within the apartment units, and latrines within each unit. Pumping of the water from on-site wells to the overhead tanks was, however, quite erratic. For this reason many of the latrines were reportedly not in use. In the area between Communities #1 and #3 (Figure 2) there was also a public latrine which, due to scarcity of water, was rarely used by children.

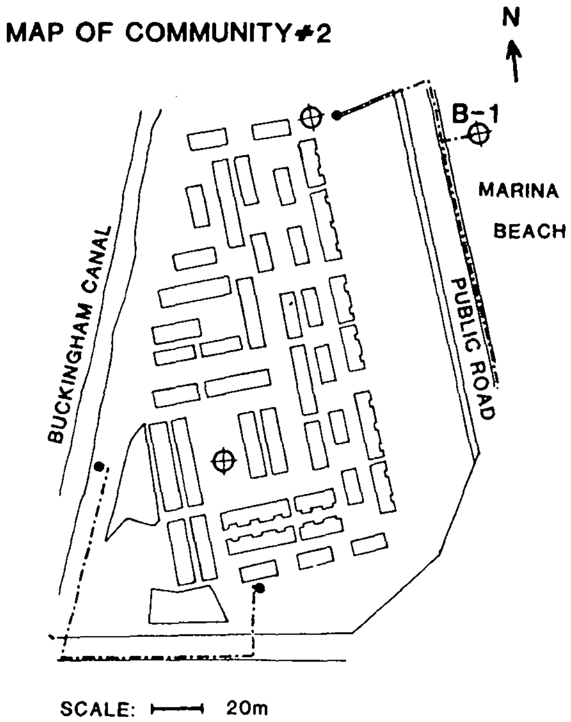

FIGURE 3

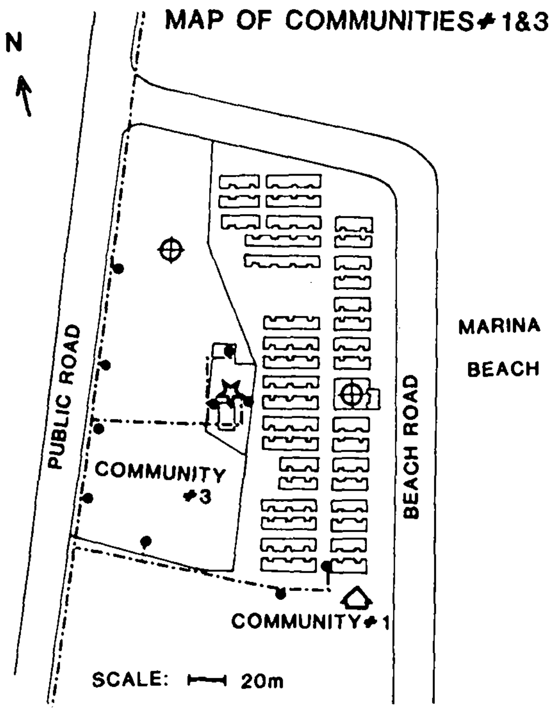

FIGURE 2

Other Components of Study Design

The study was conducted longitudinally from November 1978 to January 1980. Children in the tenements were selected by randomly assigning households for inclusion in the study. All households in the traditional housing area were included. Any child 72 months of age or younger at the beginning of the study was included. A total of 627 children were measured after the monsoon of 1978–9, beginning in January 1979. A second set of measurements was taken during the dry season 1979 and a third one was performed during the monsoon of 1979–80, ending in December 1979. One hundred and twelve children were lost in the interval between the first and second measurements and 175 were unavailable at the time of the third measurement. Based on anthropometric data, there were no significant differences between children who remained in the study and those that were lost to follow-up. Additional information relating to the timing of the study, selection of the children, data collection forms, age determination, loss to follow-up and personnel have been documented elsewhere.[10]

Predictor Variables

Many of the variables thought to be important in determining a child's nutritional status were condensed into summary sets of predictor variables. These included: socioeconomic status (mother's and father's education, family income and food cooking equipment), housing (the construction of the roof and floors of the house, water storage facilities and sanitary facilities), and food-related variables (food expenditure per person per day and food storage and preservation). In addition, information on father's occupation, proximity of the home to the sea, present breast feeding status, food withholding in the two-week period prior to the child's measurement, volume of drinking and cooking water stored and the bacteriological quality of cooking and drinking water were also included in the analyses.

The variables bathing and defaecation are used in the analysis as ones potentially under the direct discretionary control of the child. Bathing is treated here as a dichotomous variable; either the children of the household are reported as bathing regularly in the household (bathing = 2) or they use a place outside the home, probably the sea (bathing = 1). Defaecation is described as either employing a latrine (defaecation = 3), or using designated areas away from home (defaecation = 2), or using walkways or roadside areas close to home (defaecation = 1).

TABLE 1 *Distributions of continuous variables used in analyses.*

Variable	Value	Frequency (%)	Mean	S.D.
Mother's education (years)	none	62.2	2.06	3.08
	1-4	12.5		
	5-8	19.8		
	> 8	5.5		
Father's education (years)	none	30.8	4.10	3.45
	1-4	18.2		
	5-8	39.5		
	> 8	11.6		
Family income (rupees per person per month)	< 22.25	23.6	37.07	21.99
	22.25-31.24	24.8		
	31.25-44.99	26.1		
	> 45	25.5		
Food expense (rupees per person per day)	< 0.86	25.2	1.09	0.30
	0.86-1.00	30.8		
	1.01-1.25	22.0		
	> 1.25	22.1		
Drinking water use (litres per person per day)	< 6.66	19.9	10.84	6.57
	6.66-9.99	28.4		
	10.00-13.33	31.0		
	> 13.33	20.7		
Water quality (mean log coliform organisms/100 ml)	< 1.33	23.7	2.97 (geometric mean = 19.49)*	1.69
	1.33-2.99	26.2		
	3.00-4.32	24.2		
	> 4.32	25.9		

* This represents the antilog of the overall mean log coliform concentration.

TABLE 2 *Distributions of ordinal and nominal variables used in analyses.*

Variable	Value	Frequency (%)
Food cooking equipment	Open fire/ground level	31.5
	Mud hearth/knee level	19.0
	Concrete hearth/knee level	38.5
	Charcoal/kerosene stove	11.0
Floor construction	Earthen	14.9
	Plaster over brick	33.7
	Concrete	51.4
Roof construction	Palm/leaves	17.7
	Tin	14.9
	Concrete	67.4
Water storage in overhead tank	None	59.2
	Some	40.8
Food preservation	None	89.5
	Some	10.5
Father's occupation	Fisherman	53.8
	Not fisherman	46.2
Proximity to sea	25-150 metres	36.2
	151-300 metres	36.3
	> 300 metres	27.5
Plumbing wastepipes	Not present	16.8
	Present	83.2
Child's bathing*	Away from home	50.1
	At home	49.9
Child defaecation*	Near home	25.7
	Away from home	37.4
	Use a latrine	36.9
Mother's defaecation*	No latrine	9.0
	Use a latrine	91.0
Father's defaecation*	No latrine	57.5
	Use a latrine	42.5
Water treatment* (boil and/or filter)	No	66.1
	Yes	33.9
Clothes washing*	Away from home	49.9
	At home	50.1
Wash water availability*	No separate supply	39.9
	Separate supply—hand carry	23.0
	Overhead tank	37.1

		Per cent by age category		
		0-18 months	19-36 months	> 36 months
Breast feeding	no	30.9	86.9	99.2
	yes	69.1	13.1	0.8
Food withholding	yes	18.9	25.4	24.9
	no	81.1	74.6	75.1

* This variable is used in the second stage of the analyses.

Household sanitation is a variable composed of mother's and father's defaecation habits (latrine use = 2, no latrine use = 1), household clothes washing (at home facilities = 2, away from home = 1) and a simple dichotomous variable describing whether or not the family treats drinking or cooking water in any way before using it (treatment = 2, no treatment = 1).

Wash water availability represents the third type of sanitation-related variable, one which was not under the direct discretionary control of any family member. Wash water availability was recorded as an ordinal variable where "1" indicates no direct (ie overhead tank) access or separate storage facility for wash water within the household, "2" indicates no direct access but a separate wash water supply stored within the household and "3" indicates a ready supply of accessible water from an overhead tank or, rarely, directly from a well. In order for the in-house latrine to function properly, wash water would have to be available within the house. The distributions of all the variables used in analyses are shown in Table 1, for continuous variables, and Table 2, for nominal and ordinal variables.

Outcome Variables

For each set of measurements, the weight of a child was compared to the median weight of children of the same height or length in the NCHS/CDC/WHO reference series. Per cent weight-for-height or length was found by dividing the actual weight by the reference median weight and multiplying the quotient by 100. Height-for-age and weight-for-age were derived by similar methods.

STATISTICAL METHODS

The data were stratified by age. Measurements from children under 18 months of age comprised one group, those from 18 months to 36 months, a second group and those over 36 months made up the third group.

The intercorrelations among the covariates were typically (> 95%) in the range of |0.10| to |0.45| and averaged approximately |0.21|. Because of the large size of the data set, many correlation coefficients were highly significant. Relationships among some of the predictors, such as water quality/water treatment and breast feeding/food withholding, present possibilities for effect modification. Therefore, in the process of exploratory data analysis, the possibilities of interactions were also tested. Several variables were found to interact.

TABLE 3 *Model of weight-for-height.*

Age (months)	Variable	Mean	B	P-value	$BX_{(25)}$*	$BX_{(75)}$†
0–18	Intercept		101.90			
	Bathing	1.51	+0.99	0.64	+ 0.99	+ 1.98
	Defaecation	2.01	−0.14	0.90	− 0.14	− 0.42
	Household sanitation	6.15	−1.43	0.16	− 7.15	−10.01
	Wash water availability	2.02	+0.67	0.53	+ 0.67	+ 2.01
	Linear predictor score	− 2.20	+0.97	0.001	− 3.98	− 0.005
				Model R^2 = 0.07		
				N = 218		
19–36	Intercept		104.17			
	Bathing	1.50	−0.62	0.62	− 0.62	− 1.24
	Defaecation	2.05	+1.34	0.03	+ 1.34	+ 4.02
	Household sanitation	6.22	−0.02	0.97	− 0.10	− 0.14
	Wash water availability	1.94	−0.45	0.46	− 0.45	− 1.35
	Linear predictor score	−10.25	+0.97	0.0001	−12.25	− 8.35
				Model R^2 = 0.11		
				N = 348		
over 36	Intercept		94.15			
	Bathing	1.50	+0.55	0.39	+ 0.55	+ 1.10
	Defaecation	2.07	−0.62	0.05	− 0.62	− 1.86
	Household sanitation	6.18	0.00	1.00	0.00	0.00
	Wash water availability	1.97	+0.10	0.77	+ 0.10	+ 0.30
	Linear predictor score	0.72	+0.96	0.0001	− 0.02	+ 1.37
				Model R^2 = 0.04		
				N = 850		

* This represents the product of the estimate in the regression model times the twenty-fifth percentile value of the variable.

† This represents the product of the estimate in the regression model times the seventy-fifth percentile value of the variable.

A technique has been devised that controls for potentially confounding variables that are known, or thought, to be important in determining health status. This technique requires fitting a general linear model in two stages. As the first stage, each anthropometric index, weight-for-height, weight-for-age and height-for-age is regressed on variables other than those that form the subject matter of this paper: ie all those non-sanitation variables listed above and not denoted by asterisks in Tables 1 and 2. The coefficients of these regression equations are then used to compute a linear predictor score which is described in Appendix I. The linear predictor score accounts for the combined effect of all these variables aside from those related to personal habits of bathing and defaecation, household sanitation and wash water facilities. Since it is composed of the sum of the 'nuisance' variables times their regression coefficients, the linear predictor score is an entity whose units are the same as that of the anthropometric index upon which it based.

In the second stage, the variables of direct interest are entered, along with the linear predictor score from the first stage. Here, the second stage of the analyses consists of regressing the anthropometric indices on the linear predictor score, derived in the first stage, plus all of the sanitation variables. The regression coefficients of the sanitation variables then represent the effects of those variables after controlling for the linear predictor score.

All regression coefficients and associated P-values are based on type III sums of squares.[41] That is, the analyses account for the test variable with all the other variables in the model.

RESULTS

The results of the three general linear models using the variables bathing, defaecation, household sanitation, wash water availability and the linear predictor score as predictors and the indices weight-for-height, weight-for-age and height-for-age as outcome are shown in Tables 3, 4 and 5, respectively. Each table includes a list of all the predictor variables included for each of the three age groups, 0–18, 19–36 and over 36 months. In addition, the mean values, estimates of the regression coefficients (B), P-values of the test; Ho: B = 0, and the fitted values $BX_{(25)}$ and $BX_{(75)}$ are presented for all the

TABLE 4 *Model of weight-for-age.*

Age (months)	Variable	Mean	B	P-value	$BX_{(25)}$*	$BX_{(75)}$†
0–18	Intercept		70.24			
	Bathing	1.51	+1.21	0.59	+1.21	+2.42
	Defaecation	2.01	−0.71	0.52	−0.71	−2.13
	Household sanitation	6.15	+0.13	0.91	+0.65	+0.91
	Wash water availability	2.02	+0.51	0.66	+0.51	+1.53
	Linear predictor score	6.83	+1.01	0.0001	+4.79	+9.09
				Model $R^2 = 0.09$		
				N = 220		
19–36	Intercept		74.62			
	Bathing	1.50	−3.76	0.02	−3.76	−7.52
	Defaecation	2.05	+1.35	0.07	+1.35	+4.05
	Household sanitation	6.22	+1.29	0.10	+6.45	+9.03
	Wash water availability	1.94	−0.45	0.56	−0.45	−1.35
	Linear predictor score	−0.39	+0.97	0.0001	−2.41	−2.31
				Model $R^2 = 0.15$		
				N = 351		
over 36	Intercept		70.05			
	Bathing	1.50	−1.63	0.07	−1.63	−3.26
	Defaecation	2.07	−0.82	0.05	−0.82	−2.46
	Household sanitation	6.18	+0.97	0.03	+4.85	+6.79
	Wash water availability	1.97	+1.29	0.005	+1.29	+3.87
	Linear predictor score	2.88	+1.01	0.0001	+1.88	+3.77
				Model $R^2 = 0.04$		
				N = 850		

* This represents the product of the estimate in the regression model times the twenty-fifth percentile value of the variable.

† This represents the product of the estimate in the regression model times the seventy-fifth percentile value of the variable.

TABLE 5 *Model of height-for-age.*

Age (months)	Variable	Mean	B	P-value	$BX_{(25)}$*	$BX_{(75)}$†
0–18	Intercept	-	84.43			
	Bathing	1.51	−0.11	0.91	−0.11	−0.22
	Defaecation	2.01	−0.47	0.33	−0.47	−1.41
	Household sanitation	6.15	+0.69	0.15	+3.45	+4.83
	Wash water availability	2.02	+0.18	0.72	+0.18	+0.54
	Linear predictor score	5.34	+0.91	0.002	+4.26	+5.56
				Model $R^2 = 0.07$		
				N = 221		
19–36	Intercept		80.38			
	Bathing	1.50	−2.38	0.003	−2.38	−4.76
	Defaecation	2.05	+0.04	0.92	+0.04	+0.12
	Household sanitation	6.22	+1.11	0.005	+5.55	+7.77
	Wash water availability	1.94	−0.06	0.89	+0.06	+0.18
	Linear predictor score	5.92	+0.92	0.0001	+4.34	+6.65
				Model $R^2 = 0.12$		
				N = 350		
over 36	Intercept		85.08			
	Bathing	1.50	−1.36	0.006	−1.36	−2.72
	Defaecation	2.07	−0.16	0.49	−0.16	−0.48
	Household sanitation	6.18	+0.60	0.01	+3.00	+4.20
	Wash water availability	1.97	+0.84	0.001	+0.84	+2.52
	Linear predictor score	1.70	+1.10	0.001	+1.50	+2.17
				Model $R^2 = 0.03$		
				N = 853		

* This represents the product of the estimate in the regression model times the twenty-fifth percentile value of the variable.

† This represents the product of the estimate in the regression model times the seventy-fifth percentile value of the variable.

variables. The fitted values $BX_{(25)}$ and $BX_{(75)}$ are equal to the coefficient multiplied by the 25th and 75th percentile values of the predictor variable. The difference between the fitted values of $BX_{(75)}$ and $BX_{(25)}$ tends to be inversely related to the P-values; ie if P is low ($= < 0.05$) then the effect of fitting the variable in the model is relatively greater than if P is large.

Table 3 shows that in the two older age categories the reported use of a latrine is a significant predictor of weight-for-height ($P = 0.03$ for 19–36 month-olds and $P = 0.05$ for children over 36 months of age). In the middle age group, latrine use is positively associated with weight-for-height whereas for the older children latrine use is negatively associated. Reported bathing place shows an inverse pattern, although in neither age group is it significant.

Table 4 shows the results of the weight-for-age model. Coefficients for defaecation show a pattern nearly identical to those displayed in Table 3 (weight-for-height) but the P-value is not significant ($P = 0.07$) for the middle age group (19 to 36 months). In this intermediate age group bathing in the home is negatively associated ($P = 0.02$) with outcome. For the oldest children the situation is quite different. The regression coefficient for bathing is not significant and for defaecation is significant at $P = 0.05$. The differences in the fitted values, $BX_{(75)} - BX_{(25)}$, are relatively small (−1.63 and −1.64, respectively). For these older children, both household sanitation and wash water availability are positively associated with outcome ($P = 0.03$ and $P = 0.005$, respectively). The difference between the fitted values, $BX_{(25)}$ and $BX_{(75)}$, has the greatest impact on the predicted value of the anthropometric index; [$BX_{(75)} - BX_{(25)} = 2.58$ for wash water availability and 1.94 for household sanitation].

The height-for-age model given in Table 5 shows that for children 18 to 36 months old, bathing and household sanitation are significant ($P = 0.003$ and $P = 0.005$, respectively). Again, bathing at home is negatively associated with height-for-age. Household sanitation is positively associated with outcome and highly significant for the 19 to 36 month-old children ($P = 0.005$).

As with the children 19–36 months old, for the children over 36 months of age household bathing is negative whereas household sanitation is positive ($P=0.006$ and $P=0.01$, respectively). However, for these children, wash water availability is the most significant of all variables. The effect of wash water availability is the greatest—[$BX_{(75)}-BX_{(25)}= +1.68$ vs -1.36 for bathing and $+1.20$ for household sanitation]. Reported place of bathing is also highly significant as a determinant of height-for-age for the older age groups ($P=0.006$) and the regression coefficient is negative.

DISCUSSION

For children over 18 months old bathing was important as a determinant of the less labile age-dependent indices and its coefficient consistently had a negative sign. An apparent explanation is that getting outside the house, especially to the ocean, where water is more plentiful and/or conserving household water has a beneficial effect. Another explanation is that children who go away from home to bathe are healthier anyway.

Defaecation, the other child-oriented behaviour, was barely significant as a determinant for the more labile indices based on child's weight and not at all significant as a predictor of height-for-age. The change in the sign of the regression coefficient has two likely explanations. One is that self-selection by older children may explain the positive effect of beach-side defaecation in a way similar to that proposed for out-of-house bathers. The other is that there may be real age-specific differences in terms of effect.

Generally, household sanitation, the variable under control of parents, had a positive effect which increased with age within the models and as one went from the most to the least labile index. Wash water availability tended to be very important for the oldest children. This may indicate that children have to be older, probably over 36 months of age, to benefit from provision of this resource.

The fact that neither household sanitation nor wash water availability was significant in the older ages for the weight-for-height model, approximating short-term health/nutritional status, would argue against it being simply an age-specific phenomenon. It is more likely that these factors operate over longer periods of time, possibly starting when a child begins walking.

For wash water availability, only the children over 36 months of age have a significant result in any model and for these it appears to be a strong influence, especially in terms of height. This result is consistent with a stronger age/term effect; that is, it operates over time so that it cannot be seen in the labile index, weight-for-height, and is more easily detected in the height-for-age model than in the weight-for-age model. It also appears to affect children at older ages.

Of all the variables considered, factors under the direct control of some member of the household appear to be more important for children between the ages of 19 and 36 months of age. After three years of age, simple provision of the facility appears to matter most.

The models tend to have low R-square values. The inability to explain much of the variability in the dependent variables may have four causes. First, the homogeneity of these groups made detection of real differences for a range of determinants more difficult than it would have been in a very heterogeneous group. The second possible reason is related to the 'noise' in such experimental systems. Many of the real determinants of nutritional status are extremely difficult to measure, whereas anthropometric measurements can be extremely precise. Behaviour is a complex of many variables and it is likely that some important questions were not asked.

A third reason is that the variables under the direct discretionary control of the children, place of bathing and defaecation, were reported by a third party, the female head of the household. In nearly all studies reports of behaviour and morbidity experience of young children are made by parents or guardians.[32,42] Still, any variable that is reported by a third party and cannot be directly verified may have been misreported. Last, washing and defaecation practices are sensitive topics about which information may be deliberately withheld or distorted.

This study has revealed two unexpected findings. These are that use of an indoor latrine, but not its presence, appears to be associated with small body size of children over 36 months of age and use of outside bathing facilities benefit children over 18 months of age. Also, simple availability of water for washing seems to have a greater effect on health/nutritional status for children over 36 months of age than any of the 'discretionary' variables measured.

Other factors which were not considered here may also be important determinants of health or nutritional status. Despite the fact that in previous work these infants were shown to be deleteriously affected by water contamination,[10] it may be that they are essentially unaffected by sanitary practices of adult members of the household. Since a baby's environment is nearly completely mediated by family members and the huge problems of morbidity and mortality associated with infancy in the Third World are conventionally thought to be related to sanitation and infection it is something that warrants study in greater detail. For instance, the distribution of water resources within the household for bathing and washing and specific sanitary aspects of infant care should be considered in future work.

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APPENDIX I

Derivation and Properties of The Linear Predictor Score

The outcome variable, Y, the anthropometric index, is assumed to be linearly related to the sanitation-related variables, $X = (X_1 \ldots X_p)$, and to the other covariates, $Z = (Z_1 \ldots Z_q)$, as well. The true model may be represented as follows:

$$Y = \alpha + \sum_{i=1}^{p} \beta_i X_i + \sum_{j=1}^{q} \theta_j Z_j + error \qquad (1)$$

With regard to testing hypotheses concerning the sanitation-related variables, the other variables may be viewed as 'nuisance' variables. Therefore the effect of the household and behavioural variables is summarized by means of a linear predictor score, Z_0. This is done by constructing a model,

$$Y = \alpha_0 + \sum_{j=1}^{q} \theta_j Z_j \qquad (2)$$

and letting

$$Z_0 = \sum_{j=1}^{q} \theta_j Z_j \qquad (3)$$

The final model, which now includes the sanitation-related variables, is given by:

$$Y = \alpha + \sum_{i=1}^{p} \beta_i X_i + \theta_0 Z_0 \qquad (4)$$

This approach has the advantages of summarizing the 'nuisance' variables into a single score, of reducing the number of variables in the final model, of taking into account the variables known to influence child growth and of focusing the attention on the variables of interest.

It has been established, by simulation technique, that the full model (equation 1) and the final model (equation 4) yield virtually identical values for the predicted value of the coefficients, B_i, and their standard deviations when the true B values are 0.[10] That is, if sanitation-related variables do not affect anthropometry, the use of linear predictor scores will not change the Type I error rates; the probability of claiming an effect of sanitation-related variables when none is actually present. Furthermore, this holds true whether or not the X and Z variables are correlated. This is a very important factor for any data from the field studies in the Third World, where intercorrelations among variables must be expected.

If the true B values are non-zero, using equation 4 instead of equation 1 still yields nearly identical estimates of B_i though their standard deviations may be increased. With the large sample sizes in this study, the effect on significance levels of the B terms is not likely to be important.