The Relationship Between Literacy and Feeding Patterns on Infant Mortality: The Interaction with Water and Sanitation

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OTR-2199

INTRODUCTION

Efforts to improve health as a result of water or sanitation programs have met with variable success (Esrey and Habicht, 1984). Some studies have failed to find a positive health impact after water or sanitation conditions were improved, other studies found large impacts. The reasons for these inconsistent results are many (Blum and Feachem 1983, Esrey and Habicht 1984), but one important consideration is to identify a population that will respond to water or sanitation improvements.

A recent analysis (Butz et al, 1984) reported that infants in Malaysia that were not breastfed had a significantly lower infant mortality rate (IMR) if piped water or toilets were made available to the household. On the other hand, water or sanitation improvements did not result in significantly lower IMRs where breastfeeding was commonly practiced. This paper attempts to extend the analysis by Butz et al (1984) by examining water and sanitation conditions in light of other variables. These new variables are mother's education, infant feeding practices other than breastfeeding, crowding conditions, and family income to see if these factors also affected the improvement due to water and sanitation.

For some of these factors it was possible to establish a priori hypotheses for the affect water or sanitation conditions would have on infant mortality rates. The following hypotheses were established.

Hypothesis 1 - the addition of toilets will significantly lower IMRs in households where the mother is illiterate, but not in households where the mother is literate. This is because literate mothers presumably have better hygiene practices than illiterate mothers; thus, IMRs in the latter group are already lower than for the illiterate.

Hypothesis 2 - Providing piped water could either improve water quality or increase the quantity of water used. If there was only a difference in the quality of water used by the literate and illiterate, only the illiterate would be expected to benefit since the literate would already be decontaminating water in some manner (i.e. boiling) which protected their infants. If piped water increased the availability of water for domestic hygiene, infants from literate mothers would be expected to benefit more than infants from illiterate mothers. This is because literate mothers would know how to utilize the available water for good domestic hygiene practices. We do not know which type of benefit resulted from the piped water, therefore, a two-tailed test will be used (see methods).

Hypothesis 3 -We would expect piped water to be protective when non-milk and infant powder was introduced as the first food, but not for sweetened condensed milk. This is because non-milk food and infant powdered milk become contaminated when polluted water is used for its preparation. Since non-milk foods allow bacteria to multiply rapidly, the benefit would be greatest for this type of food. The high sugar content of sweetened condensed milk prevents bacterial growth; therefore, piped water would confer no benefit when this food is first introduced.

Hypothesis 4 - The impact from toilets on IMRs for users of sweetened condensed milk is not known, but since it precludes bacteria from multiplying no benefit would be expected. For non-milk and infant powdered milk some benefit may be expected, but it would depend on the method of preparation and how these food products are stored.

Hypothesis 5 - Toilets would be expected to benefit crowded families less than uncrowded families, because hand-to-hand transmission of enteric pathogens will be greater in crowded families. The reduction of diarrheal diseases prevented by improved toilets will be less.

Hypothesis 6 - Piped water would be expected to benefit crowded families more than uncrowded families because increased quantity of water for hand washing will tend to break hand-to-hand transmission of enteric pathogens.

Hypothesis 7 - It would be expected that water and sanitation improvements would lower infant mortality rates to a greater extent in families with low income than in families with higher income, thus reducing the gap in income differentials. This is because higher income families could devote more resources for child care (e.g. medical care), to compensate for poor environmental conditions while this would not be possible for poor families.

METHODS

The data used in these analyses are from the Malaysian Family Life Survey and were collected during a series of three interviews, 1976-1977 (Butz et al, 1982). The sample consisted of randomly selected private households that each contained at least one ever-married woman under 50 years of age. The households were contained in 52 primary sampling areas in peninsular Malaysia. Forty-nine were randomly selected; three were purposefully selected for additional representation to the Indian and fisherman populations.

These retrospective data contain information on 5355 live singleton births, which are the unit of analysis. The sample contains two fewer observations than previous publications (Butz et al 1982, Butz et al 1984) because non-Asian babies were excluded from the analyses. Behavioral and demographic data associated with each live birth were collected through a retrospective life history questionnaire. Factors previously identified and known to influence mortality during the first year of life in these data were used as a starting point in these analyses (Butz et al, 1982).

The variables used in these analyses include information on the infant (year of child's birth, child's birthweight, ethnicity, duration of full and partial breastfeeding, sex, and first food other than breastmilk introduced to the mother's first and last child) and on the mother or household (income, previous pregnancy interval, rurality, literacy, and crowding conditions). Variables chosen for the interaction have been defined in the following manner: literacy - those who read are classified as literate (n=2502), and those who can't read are classified as illiterate (n=2853); crowding - the uncrowded group is defined as those infants whose families have less than or equal to 3 people per room (n=4028), and the crowed group has greater than three people per room (n=1327); income - divided into two levels at the median figure, 2319 Malaysian dollars, the higher income group has a sample of size 2632 and the lower income group has a sample of size 2723; and first food given to the infant - defined as the first milk given to the baby apart from breastmilk. These data on first foods were only available for the first and last babies born to the mothers in the survey. Three levels were created as follows: non-milk foods (n=1316), powdered infant milk (n=1657), and sweetened condensed milk (n=1966). The analyses of first food contain only 4939 total observations because some mothers did not recall what foods were first offered and other food categories contained too few observations (e.g. fresh goat's and cow's milk, evaporated milk, and other non-infant powdered milk).

Analyses were made with and without breastfeeding controlled. Analyzing the effect of breastfeeding on infant mortality overestimates the benefits of breastfeeding (Butz et al, 1982) unless complicated correction factors are introduced. Since the effect of breastfeeding is not the object of these analyses, the analyses have been run without these corrections. The object of comparing analyses with and without duration of total breastfeeding as a covariate was to see if breastfeeding affected the impact of the variable being investigated. In some cases there was no difference between the two models; in these cases only one analysis was presented.

When choosing statistical models to test for the presence or absence of interactions, some investigators advocate additive scales (Blot and Day, 1979; Rothman et al, 1980; and Saraci, 1980) while others advocate multiplicative scales (Bishop et al 1975). The additive scale, linear probility model (OLS), has an advantage in that attributable risks can be estimated; additivity of attributable risks can be tested. Another kind of analysis, the logit procedure, provides estimates of relative risks. For addressing public health concerns it has been suggested that additive scales may be the most revelant (Kleinbaum et al, 1982). Because of this argument we have used the linear probility model for ease of interpretation. This OLS procedure is not strictly correct for dichotomous data such as mortality data, but the statistical tests of the regression coefficients are unbiased (Hagerstrom, 1983). Previous publications on these data have also used the additive scale (Butz et al, 1982; Butz et al, 1984).

The statistical model used in these analyses is a general means model and has the form $y_{ij} = u_{ij} + \varepsilon$ (where y_{ij} = the outcome mortality, u_{ij} represents each cell mean for the two-way analysis of variance, i = level of factor A, and j = level of factor B). Although this model is different from previous publications (Butz et al, 1984), tests of contrasts can be derived directly from the parameter estimates (see results). Coefficients from the previous publication are repeated here to ascertain the comparability of models. Statistical significance was assumed at the 0.05 level using a one-tailed test for the a priori hypotheses and a two-tailed test for those tests in which a priori hypotheses were not established.

RESULTS

Table 1 compares the coefficients by Butz et al (1982) with those used in these analyses illustrating the case for the main effect of toilets. The model used in these analyses provide comparable estimates. The variable rurality, despite its insignificance, is included in the model because previously published results in the literature have often been confounded by this factor. The estimate of previous interpregnancy interval is different in the two models. This is because in model 1 (that of Butz et al, 1982) it was entered as a dummy variable taking a value of 1 if the interval was less than 15 months. In the present analyses it was entered as a continous variable. Even though parameter estimates are different, the effect they have on estimates of mortality due to toilets is negligible. For example, the test for the main effect of toilets reduces mortality by similar amounts and is statistically significant in both cases (model 1 and 2 of table 1).

The interaction of toilets and literacy, table 2, not controlling for breastfeeding, was significant at p <.02 (figure 1). The addition of toilets to households where mothers were illiterate reduced IMRs by 35.3 deaths per 1000 live births (p <.0003). In the case of literate mothers there was an insignificant rise in the IMR of 1 death per 1,000 live births (p >.4). This effect is reduced when breastfeeding is introduced into the model, and the test for interaction becomes insignificant at p >.1, one-tailed (column 2 of table 2). For the illiterate case the reduction in the IMR was 30.2 (p <.002) and for the literate case the reduction was 10.7 (p >.2).

No interaction (p >.9) between type of water supply and mother's literacy was found (column 1 of table 3) and is illustrated in figure 2. Both literate and illiterate groups had a similar reduction in IMRs of about 23 when piped water was present compared to non-piped water. The largest benefit may be expected during the latter half of infancy when water is used for the preparation of supplemental foods. Contaminated water used for food preparation may infect infants in which case better quality water would benefit the illiterate who presumably do not take protective measures as might literate mothers. To investigate this possibility the analysis was repeated with only those infants who were breastfed at least 4 months (figure 2). Regression coefficients for this analysis appear in column 2 of table 3 and are illustrated in figure 2. In this case the illiterate group benefitted significantly better than the literate group from piped water. This would suggest a water quality difference between the piped and non-piped groups. IMRs among the illiterate dropped by 24.6 (p <.002, two-tailed) and among the literate the drop was 7.1 (p >.3, two-tailed). The test for interaction approached significance at p <.1 (two-tailed).

If water quality differences between piped and non-piped groups exist, this difference can be further investigated by examining the interaction between water supply and type of supplemental food first given to infants. The first analysis was for the entire 12 months of infancy (table 4). A strong interaction between water supply and non-milk and other milks was significant (p <.02) and the interaction between infant powdered milk and sweetened condensed milk was also significant (p <.004), figure 3. There was a significant reduction in mortality rates when piped water was present among infants first given non-milk food (47.4, p <.002) and infant powdered milk (28.7, p <.01), but not for sweetened condensed milk. In the latter case the IMR rose by an insignificant 14.4 deaths per thousand live births (p >.2). When breastfeeding was introduced into the regression, the relationship became stronger. Toilets reduced the IMR for non-milk users 50.9 (p <.001), for infant powdered milk, 46.9 (p <.0001), but it rose by an insignificant 6 deaths for sweetened condensed milk (p >.5).

Part of this effect may be due to age differences at the time of introduction of these foods. Therefore, these analyses were repeated only with infants who breastfed at least 4 months (column 3 of table 4). Similar results as in the full 12 month analyses occurred (figure 3a). Piped water significantly reduced IMRs for users of non-milk foods by 25.8 deaths (p <.003, one-tailed) and for users of infant powdered milk by 16.9 deaths (p <.05, one-tailed) but only by an insignificant 4.7 deaths (p =.3, one-tailed) for those offered sweetened condensed milk.

In the analysis of toilets and first food toilets reduced IMRs in all cases whether or not the analyses controlled for breastfeeding (column 1 of table 5). When breastfeeding was not controlled, the interaction between non-milk and other milks with toilets was insignificant (p >.4, one tailed). The interaction between infant powdered milk and sweetened condensed milk with toilets was also insignifcant (p > .1, one-sided). For users of infant powdered milk a reduction of 36.5 deaths was achieved. For users of sweetened condensed milk the reduction was 14.4 and for non-milk it was 21.3. When duration of breastfeeding was introduced into the model (column 2 of table 5), the relationship changed (figure 4), but both tests for interaction remained insignificant in spite of a larger reduction in IMRs accruing to users of infant powdered milk (47.1) in contrast to a modest but insignificant benefit to users of sweetened condensed milk (14.4) and to non-milk users (9.8).

As was done for water supplies, those who were still breastfeeding after 4 months were analyzed (figure 4a). The interaction between toilets and non-milk and other milks was significant at $p < .05$, one-tailed (column 3 of table 5). The largest benefit was to users of non-milk foods who experienced a reduction of 19.9 deaths per 1,000 live births ($p < .05$, one-tailed). The addition of toilets to families who used infant powdered milk reduced IMRs by only an insignificant 1 death ($p > .4$, one-tailed) and increased the IMR by an insignificant 1 death for users of sweetened condensed milk ($p > .4$, one-tailed).

When the interaction between crowding and sanitation was analyzed, it was found to be insignificant whether or not the analyses included breastfeeding ($p > .2$, one-tailed). The interaction between type of water supply and crowding was also found be insignificant whether or not breastfeeding was included in the analyses (p>.3, one-tailed). No interaction between income and sanitation (p >.3, one-tailed) or income and water (p >.4, one-tailed) was found. Again this was not affected by whether or not breastfeeding was included in the model (p >.,one-sided). The main effect of income was also found to be insignificant (Butz et al, 1982).

DISCUSSION

In the analyses of toilets and literacy the test for interaction depended on whether of not duration of breastfeeding was included in the model. While it may be possible that a three-way interaction between toilets and literacy and breastfeeding was occurring, there were two few deaths in some cells to make this procedure valid. The interpretation of a three-way interaction is also very difficult. As an alternative the full model by Butz et al (1982) was run introducing the literacy by breastfeeding interaction and the previously reported toilet by breastfeeding interaction (Butz et al, 1984). In this case the toilet by literacy interaction was still significant (table 6). It appears that breastfeeding duration overestimated the effect of breastfeeding and masked the interaction.

While the results of the analysis on literacy and toilets are in agreement with our original hypothesis, they are not in agreement with an analysis of infant mortality in Sri Lanka (Megeema, 1980). In that analysis toilets benefitted infants from literate families in the neonatal period, but no interaction was found during the postneonatal period. The Sri Lankan anaylsis, which also used retrospective data, pooled mortality events over a 25 year period, but all independent variables pertained only to conditions in one year, 1975. As conditions have improved over the years in Sri Lanka, misclassification would bias results toward the null hypothesis of no interaction. That is, the estimate of the IMR in the illiterate group with no toilets would be underestimated, while the other 3 cells would be overestimated. Thus, removing this bias could only support our findings, not negate them.

It could be that the mechanism we have proposed, literate mothers practice better hygiene, is incorrect. Literate mothers may spend more time with infants or provide better quality care, which could be unrelated to hygiene. We can rule out the former case since it was reported that mother's education was unrelated to the quantity of child care in this sample (DeVanzo and Lee, 1978). However, we cannot rule out the latter case.

In contrast to the above findings the hypothesis that piped water would preferentially benefit either the literate or the illiterate was not supported by the finding of a statistical interaction. There could be two reasons for this finding. One is that measuring the presence or absence of piped water misclassified beneficiaries of better or more water. The second possible reason is that babies of both illiterate and literate mothers benefitted but for different reasons.

In this sample piped water was known to have less of an effect than toilets in lowering IMRs (Butz et al, 1982). Part of this may be explained by a misclassification bias. It is well known that piped supplies are subject to breakdowns because of poor maintenance and lack of parts for repairs (Levine, 1974). If this occurred, then some of those incorrectly classified as having piped water should have been classified non-piped because of their use of alternative water supplies. Any positive effect of improved water would be hidden by this misclassification. Although the extent of this misclassification is not known and is poorly documented in the literature (Esrey and Feachem, 1984), this bias would only underestimate true differences in mortality rates. However, piped water was found to be beneficial (Butz et al, 1982), particularly among non-breastfed infants (Butz et al, 1984).

Since it was possible that piped water provided an improved quality drinking water and increased accessibility and use of water, an interaction was masked. When piped water is not available the illiterate are worse off than the literate (figure 2). Literate mothers presumably decontaminate unpure drinking water, whereas the illiterate do not. Providing good quality water closes the gap in IMRs between the literate and illiterate. Providing a larger amount of water over and above the improved quality would then benefit the literate because they have better hygiene practices and know how to use the increased water provided. In this case infant mortality rates between the literate and illiterate would widen again. Thus, no interaction would be found, but a main effect of literacy would be found. Literacy was found to have a strong main effect in these analyses.

This type of effect became clear when the analysis of the infants who were still breastfed at 5 months of age was examined. The illiterate benefitted more than the literate from piped water as hypothesized. In this case the test of interaction was statistically significant, but the main effect of literacy was removed. Since infants in this age group are receiving water for drinking and food preparation, the benefit of improved drinking water became more apparent.

This possibility, that more sanitary food preparation was responsible for improved infant survival, was further examined when the interaction of water supply and the first food other than breastmilk given to infants was analyzed. Although previous analyses of first food given to infants showed no differences in IMRs (Butz et al, 1982), no interaction was tested. In the non-piped group non-milk foods and infant powdered milk were all associated with higher IMRs, but they were not statistically significantly different from each other. It was not until piped water was available that differences in the IMR from these foods were detected. Piped water significantly lowered IMRs for users of infant powdered milk and non-milk, but not those consuming sweetened condensed milk.

In a study of bacterial contamination of weaning foods of children under 2 years of age in India (Mathur and Reddy, 1983) a high percentage of weaning foods were contaminated. Sweetened condensed milk was not studied. In a study in El Salvador (Soundy and Rivera, 1972) fecal contamination occurred in 17.9% of foods sampled, but only in 9.7% of chlorinated water samples, suggesting that multiplication of bacteria was occurring in foods. Again, sweetened condensed milk was not studied. It has also been reported that stored foods become more heavily contaminated over time (Barrell and Rowland, 1979; Capparelli and Mata, 1975).

Undiluted sweetened condensed milk, because of its high sugar content, and low water activity, prevent bacteria from multiplying. However, undiluted sweetened condensed milk can also be detrimental to young infants because of its high solute load which can lead to hypernatremia and eventually death.

In this sample it was not known how sweetened condensed milk was fed to infants. If it was fed undiluted, the differences in pathogen proliferation between sweetened condensed milk and other milks could explain these differences. However, previous reports suggest it was diluted and sometimes added to starchy weaning foods. (Millis, 1959 and Jelliffe, 1968). Even though diluted sweetened condensed milk may permit bacterial contamination, it can be detrimental for other reasons when compared to other infant foods. Vitamin A content is low in sweetened condensed milk and can lead to Vitamin A deficiency if fed regularly as a major constituent of the child's diet. Infants with Vitamin A deficiency will have delayed turnover of gut epithelial tissue and thereby suffer more severely from bouts of diarrhea and increasing their risk of death.

A deleterious effect of sweetened condensed milk could also be due to its unbalanced energy-protein ratio. Although this ratio is not higher than for human milk, the protein in sweetened condensed milk is less easily digested than from breastmilk. Therefore, infants fed sweetened condensed would be satiated before their protein requirements were met leading to malnutrition and death. It is interesting to note how the pernicious effect of sweetened condensed milk, whatever its cause, only becomes apparent when improved water is available.

The harmful effect of sweetened condensed milk was still apparent among those infants who were still breastfeeding after 4 months of age. Consequently, sweetened condensed milk would be contraindicated as a choice for infant food at any age under any conditions of water and sanitation.

In the analysis of toilets and first food for the full 12 month sample, the model with breastfeeding yielded very different results than the model without breastfeeding. In both cases, however, the tests for interaction were not significant. Since an interaction between breastfeeding and toilets was reported (Butz et al, 1984), it would be appropriate to examine a three way interaction; hence, our analysis may be missing some important relationship. This was not possible because some cells had too few deaths.

An examination of only those still breastfeeding after four months of age, however, yielded an interaction. The provision of toilets benefitted only those fed non-milk products. Since non-milk foods may be exposed to fecal contamination due to poor food storage practices, these non-milk foods would be contaminated prior to preparation. This may explain the higher IMRs found for those fed non-milk food products in the non-toilet group.

Crowding has been associated elsewhere with increased diarrhea (Kourany et al, 1971; Peterson and Hines, 1960; and Bruch et al, 1963) and increased malnutrition (Moore et al, 1965; and Christiansen et al, 1975). Schliessman et al (1959) in Kentucky reported that toilets benefitted crowded families. Bruch et al (1963) reported the reverse; privies were more beneficial in families of 1-3 persons when they studied diarrheal rates. The benefits of toilets in the presence of absence of crowding may be dependent on the pathogens most responsible for disease transmission.

Conflicting results for water supply and crowding have also been reported. Thacker et al (1980) noted that in a restricted water supply situation in Haiti those children from larger families with more than one can of water per person per day had less diarrhea than those with less than one can of water daily. No information was provided for smaller families. Schliessman et al (1958) in Kentucky noted that water supplied near the home reduced diarrhea more in uncrowded settings than in crowded settings. Unless water quality and quantity can be separated, conflicting and confusing results will occur.

Income was not found to be an important determinant of mortality in these data (Butz et al, 1982). In general infant mortality is determined less by income differentials than by more proximal factors such as education (Cochrane et al, 1980; Bairagi, 1980). Income by itself cannot lower mortality unless this increased wealth is translated into some action which protects a child's life. Since income serves as a proxy for many actions, these individual actions may better explain patterns of mortality than income itself. Thus, the above findings better explain differences in infant mortality rates.

In summary achieving health impacts from improvements in water supply or excreta disposal facilities is dependent on patterns of child care and feeding practices. It has been reported that sanitation is of great benefit in lowering IMRs when the baby is not breastfed (Butz et al, 1984). The above analyses exhibit that sanitation can greatly reduce IMRs when mothers are illiterate. It also found that piped water supplies, even if exclusive to the household, help reduce IMRs when weaning begins, but not if sweetened condensed milk is the food of choice. Toilets were also beneficial during the weaning process, but most likely as a measure to prevent contamination of local foods prior to their preparation.

If the findings can be replicated in different settings, then improvements in water or sanitation can be targetted to supply these services to those most in need. Benefits described above could justify the necessary investments to improve infant health and increase the effectiveness when introducing these services into the appropriate setting.

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Table 1. A comparison of parameter estimates for the present analyses and previously published reports.

PARAMETER[a]	MODEL 1[b]	MODEL 2[c]
Year of birth	-.0029 (-4.68)[d]	-.0018 (-4.19)
Chinese (D)[e]	-.0418 (-5.22)	-.0422 (-5.68)
Indian (D)	-.0319 (-3.15)	-.0202 (-1.98)
Sex = male (D)	.0324 (5.68)	.0223 (3.51)
Rurality	.00002 (0.06)	.0006 (1.89)
Prev interpreg interval	.0359 (5.68)	-.0008 (-4.74)
Birth weight spline (kg)		
<2.0	-.275 (-3.66)	.1752 (8.94)
2.0-2.5	-.143 (-3.70)	-.2486 (-6.26)
2.5-3.5	-.0297 (-2.71)	-.0087 (-0.58)
>3.5	-.0011 (-0.07)	-.0041 (-1.54)
Toilet	-.0288 (-3.64)	-.0213 (-2.55)
R^2	.0606	.0886
Sample size	5357	5355

a) For parameter selection see methods.

b) Coefficients of variables taken from previously published reports (Butz et al, 1982).

c) Coefficients of variables used in the present analyses with no interactions present.

d) Parameter estimates (t-statistics).

e) D = dummy variable.

Table 2. Parameter estimates for different models examining the interaction of toilets and literacy

PARAMETER[a]		MODEL 1[b]	Model 2[c]
Year of birth		-.0021 (-4.66)[d]	-.0026 (-5.90)
Chinese (D)		-.0425 (-5.72)	-.0859 (-11.3)
Indian (D)		-.0216 (-2.12)	-.0536 (-5.34)
Sex = male (D)		.0219 (3.46)	.0212 (3.45)
Rurality		.0004 (1.23)	.0006 (1.96)
Prev interpreg interval		-.0009 (-5.06)	-.0004 (-2.57)
Birth weight spline (kg)			
<2.0		-.2721 (-3.26)	-.2371 (-2.93)
2.0-2.5		-.1432 (-3.27)	-.1362 (-3.20)
2.5-3.5		-.0136 (-0.91)	-.0099 (-0.68)
>3.5		-.0037 (-1.30)	-.0014 (-0.51)
Breastfeeding duration			-.0056 (-17.6)
Toilet x literate[e]			
No	No	.8646 (5.38)	.8798 (5.64)
No	Yes	.8226 (5.11)	.8400 (5.37)
Yes	No	.8293 (5.17)	.8496 (5.45)
Yes	Yes	.8236 (5.13)	.8293 (5.32)
Test of interaction		.0182 (2.14)	.0098 (1.19)
Toilet main effect		-.0171 (-1.91)	-.0205 (-2.34)
Literacy main effect		-.0239 (-2.76)	-.0300 (-3.57)
R^2		.0949	.1446
Effect of toilet if			
illiterate		-.0353 (-3.47)	-.0302 (-3.06)
literate		.0010 (0.07)	-.0107 (-0.77)

a) See footnote a table 1.
b) Coefficients for model without breastfeeding controlled.
c) Coefficients for model with breastfeeding duration controlled.
d) Parameter estimates (t-statistic)
e) No-No = No toilet and illiterate; No-Yes = No toilet and literate; Yes-No = Toilet present and illiterate; Yes-Yes = Toilet present and literate. Tests of contrasts are made directly from the coefficients; for example, the test for the main effect of toilets in model 1 would be ((.8646 + .8226) - (.8293 + .8236))/2 = .0172 or a reduction of 17.2 deaths per 1,000 live births.

Table 3. Parameter estimates for the interaction between water supply and literacy for two periods of infancy

PARAMETER[a]		Literacy 1[b]	Literacy 2[b]
Year of birth		-.0024 (-5.53)[c]	-.0006 (-1.91)
Chinese (D)		-.0884 (-12.0)	-.0247 (-4.16)
Indian (D)		-.0477 (-4.53)	-.0082 (-0.94)
Sex = male (D)		.0208 (3.39)	.0095 (1.98)
Rurality		.0005 (1.72)	.0001 (0.52)
Prev. interpreg int		-.0004 (-2.44)	-.0003 (-2.43)
Birth weight spline (kg)			
< 2.0		-.2340 (-2.89)	.0560 (0.55)
2.0-2.5		-.1395 (-2.89)	.0039 (0.10)
2.5-3.5		-.0104 (-0.72)	-.0101 (-0.89)
> 3.5		-.0011 (-0.41)	-.0003 (-0.15)
Breastfeeding duration		-.0057 (-18.0)	-.0016 (-6.20)
Water x Literate			
no	no	.8544 (5.48)	-.0038 (-0.02)
no	yes	.8325 (5.34)	-.0190 (-0.10)
yes	no	.8314 (5.33)	-.0283 (-0.14)
yes	no	.8090 (5.19)	-.0262 (-0.13)
Test of interaction		.0003 (0.04)	.0087 (1.65)
Water main effect		-.0232 (-3.22)	-.0159 (-2.74)
Literacy main effect		-.0221 (-3.35)	-.0066 (-1.22)
Effect of piped water if			
illiterate		-.0229 (-2.34)	-.0246 (-3.19)
literate		-.0235 (-2.46)	-.0072 (-0.90)
R^2		.1447	.0461

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a) see table 1 footnotes for parameter definitions.

b) Literacy 1 = full 12 month sample

Literacy 2 = only those infants still breastfeeding after 4 months

c) Regression coefficient (t-statistic)

Table 4. Parameter estimates for the interaction between water supply and first food introduced other than breastmilk for two different periods of infancy.

PARAMETER[a]	First food 1[b]	First food 2[b]	First food 3[b]
Year of birth	-.0019 (-4.07)	-.0021 (-4.53)	-.0008 (-2.25)
Chinese (D)	-.0508 (-6.31)	-.0877 (-10.9)	-.0183 (-2.87)
Indian (D)	-.0260 (-2.29)	-.0472 (-4.27)	-.0019 (-0.21)
Sex = male (D)	.0188 (2.86)	.0181 (2.84)	.0075 (1.52)
Rurality	.0002 (0.67)	.0003 (1.05)	-.00002(-0.07)
Birth weight spline (kg)			
< 2.0	-.2666 (-2.87)	-.2416 (-2.68)	.0778 (0.70)
2.0-2.5	-.1640 (-3.61)	-.1585 (-3.60)	-.0093 (-0.25)
2.5-3.5	-.0136 (-0.88)	-.0087 (-0.58)	-.0042 (-0.36)
> 3.5	-.0032 (-1.09)	-.0013 (-0.44)	-.0023 (-1.05)
Prev interpreg int	-.0009 (-4.67)	-.0005 (-2.70)	-.0005 (-3.30)
Water x First food			
no non-milk	.8337 (4.68)	.8755 (5.07)	-.0578 (-0.27)
no infant powder	.8447 (4.74)	.8574 (4.96)	-.0601 (-0.28)
no sweetened condensed	.8325 (4.66)	.8494 (4.91)	-.0672 (-0.32)
yes non-milk	.7864 (4.40)	.8246 (4.76)	-.0855 (-0.40)
yes infant powder	.8161 (4.58)	.8105 (4.69)	-.0769 (-0.36)
yes sweetened condensed	.8464 (4.73)	.8554 (4.94)	-.0719 (-0.34)
Breastfeeding duration		-.0060 (-17.5)	
Test of interaction			
non-milk vs milks	.0200 (2.31)	.0152 (1.81)	.0085 (1.44)
infant powder vs sweet cond	.0213 (2.67)	.0265 (3.42)	.0061 (0.92)
Water main effect	-.0207 (-2.59)	-.0306 (-3.94)	-.0164 (-2.79)
Effect of piped water if first food was			
non-milk	-.0474 (-3.01)	-.0509 (-3.34)	-.0278 (-2.77)
infant powder	-.0286 (-2.35)	-.0469 (-3.96)	-.0169 (-1.65)
sweetened condensed	.0139 (1.26)	.0060 (0.56)	-.0047 (-0.53)
R^2	.0947	.1474	.0331

a) See table 1 footnotes for parameter definitions

b) First food 1 = full 12 month sample with no breastfeeding controls
First food 2 = full 12 month sample with breastfeeding duration controlled
First food 3 = only those infants who breastfed at least 4 months

Table 5. Parameter estimates for the interaction between toilet facilities and first food introduced other than breastmilk for two different periods of infancy

PARAMETER[a]		First food 1[b]	First food 2[b]	First food 3[b]
Year of birth		-.0021 (-4.47)	-.0023 (-5.10)	-.0009 (-2.53)
Chinese (D)		-.0486 (-5.87)	-.0871 (-10.5)	-.0194 (-2.91)
Indian (D)		-.0283 (-2.61)	-.0540 (-5.08)	-.0084 (-0.98)
Sex = Male (D)		.0179 (2.72)	.0172 (2.69)	.0075 (1.52)
Rurality		.0003 (0.77)	.0004 (1.39)	.00002(0.08)
Birth weight spline (kg)				
< 2.0		-.2675 (-2.88)	-.2427 (-2.69)	.0654 (0.59)
2.0-2.5		-.1624 (-3.57)	-.1569 (-3.56)	-.0035 (-0.09)
2.5-3.5		-.0134 (-0.87)	-.0088 (-0.59)	-.0041 (-0.35)
> 3.5		-.0032 (-1.08)	-.0013 (-0.46)	-.0023 (-1.07)
Prev interpreg int		-.0009 (-4.61)	-.0005 (-2.61)	-.0005 (-3.21)
Toilet x First food				
no	non-milk	.8480 (4.75)	.8835 (5.10)	-.0241 (-0.11)
no	infant powder	.8694 (4.85)	.8842 (5.09)	-.0395 (-0.19)
no	sweetened condensed	.8598 (4.81)	.8813 (5.08)	-.0421 (-0.20)
yes	non-milk	.8268 (4.63)	.8737 (5.05)	-.0440 (-0.21)
yes	infant powder	.8329 (4.67)	.8371 (4.84)	-.0405 (-0.19)
yes	sweetened condensed	.8454 (4.73)	.8623 (4.98)	-.0413 (-0.19)
Breastfeeding duration			-.0059 (-17.0)	
Test of interaction				
Non-milk vs milks		.0041 (0.24)	.0116 (1.39)	.0198 (1.76)
infant powder vs Sweet cond		.0111 (1.05)	.0141 (1.38)	.0009 (0.11)
Toilet main effect		-.0241 (-2.72)	-.0253 (-2.95)	-.0067 (1.09)
Effect of toilet if first food[c]				
Non-milk		-.0213	-.0098	-.0199
Infant powder		-.0365	-.0471	-.0010
Sweetened condensed		-.0143	.0190	.0008
R^2		.0831	.1447	.0317

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a) See table 1 footnotes for parameter definitions

b) First food 1 = full 12 month sample with no breastfeeding controls
First food 2 = full 12 month sample with breastfeeding duration controlled
First food 3 = only those infants who breastfed at least 4 months

c) Since the interaction was insignificant the simple effects have not been assigned probability values

Table 6. Parameter estimates for toilets by literacy interaction controlling for literacy by breastfeeding and toilet by breastfeeding interactions.

PARAMETER	ESTIMATES[a]
Year of birth	-.0021 (-4.32)[b]
Chinese (D)	-.0385 (-4.81)
Indian (D)	-.0351 (-3.45)
Sex = male (D)	.0329 (5.80)
Rurality	.0001 (0.17)
Prev interpreg interval	.0361 (4.04)
Months unsupplemented breastfeeding	-.0192 (-4.17)
Months supplemented breastfeeding	-.0140 (-6.34)
Interaction of toilet by	
unsupplemented breastfeeding	.0109 (3.09)
supplemented breastfeeding	.0089 (5.32)
Interaction of literacy by	
unsupplemented breastfeeding	.0009 (0.74)
supplemented breastfeeding	.0009 (0.40)
Interaction of toilet by literacy	.0496 (3.18)
Toilet main effect	-.1755 (-6.49)
Literacy main effect	-.0509 (-2.75)
R^2	.0718

a) These parameter estimates were provided by Chris Peterson of the Rand Corporation, Santa Monica, CA. They control for all previously published coefficients (Butz et al, 1982) along with the two-way interactions of toilets by breastfeeding and literacy by breastfeeding.

b) Parameter estimates (t-statistic)

Figure 1. Infant Mortality Rates According to the Type of Excreta Disposal Facility and Literacy of the Mother

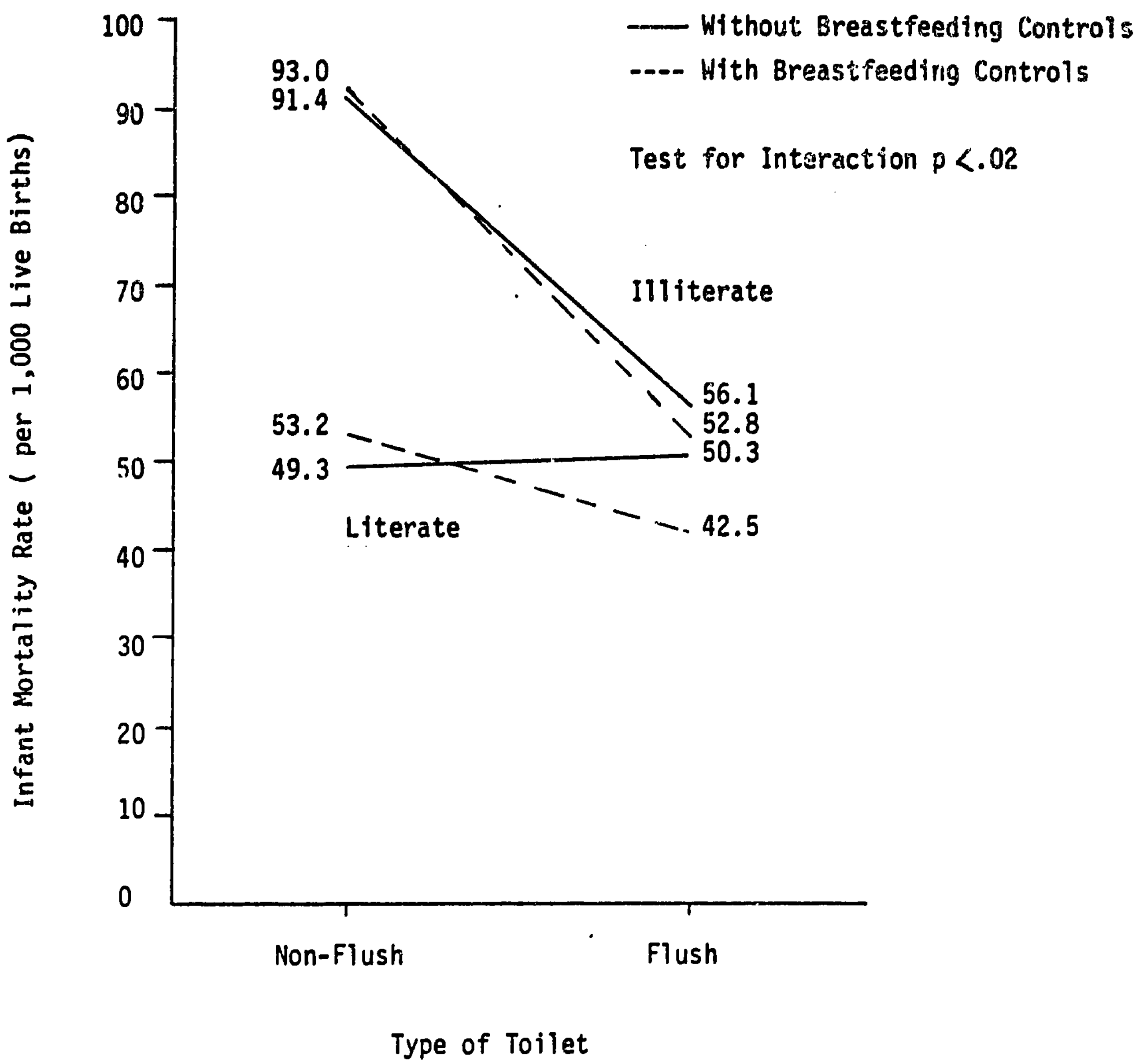

Figure 2. Infant Mortality Rates According to the Type of Water Supply Facility and literacy of the mother (breastfeeding controlled)

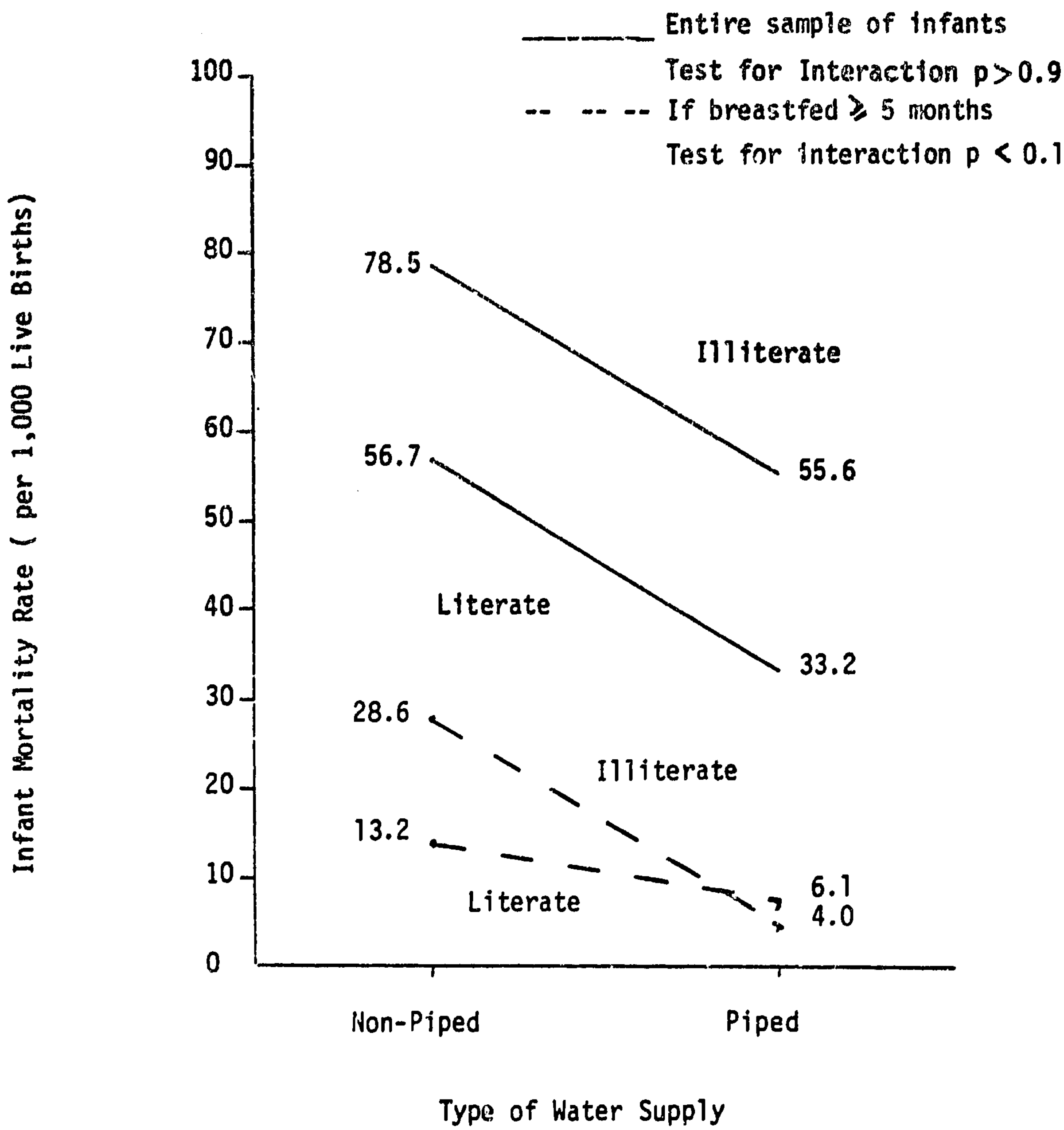

Figure 3. Infant Mortality Rates According to Water Supply and First Food Introduced Other Than Breastmilk

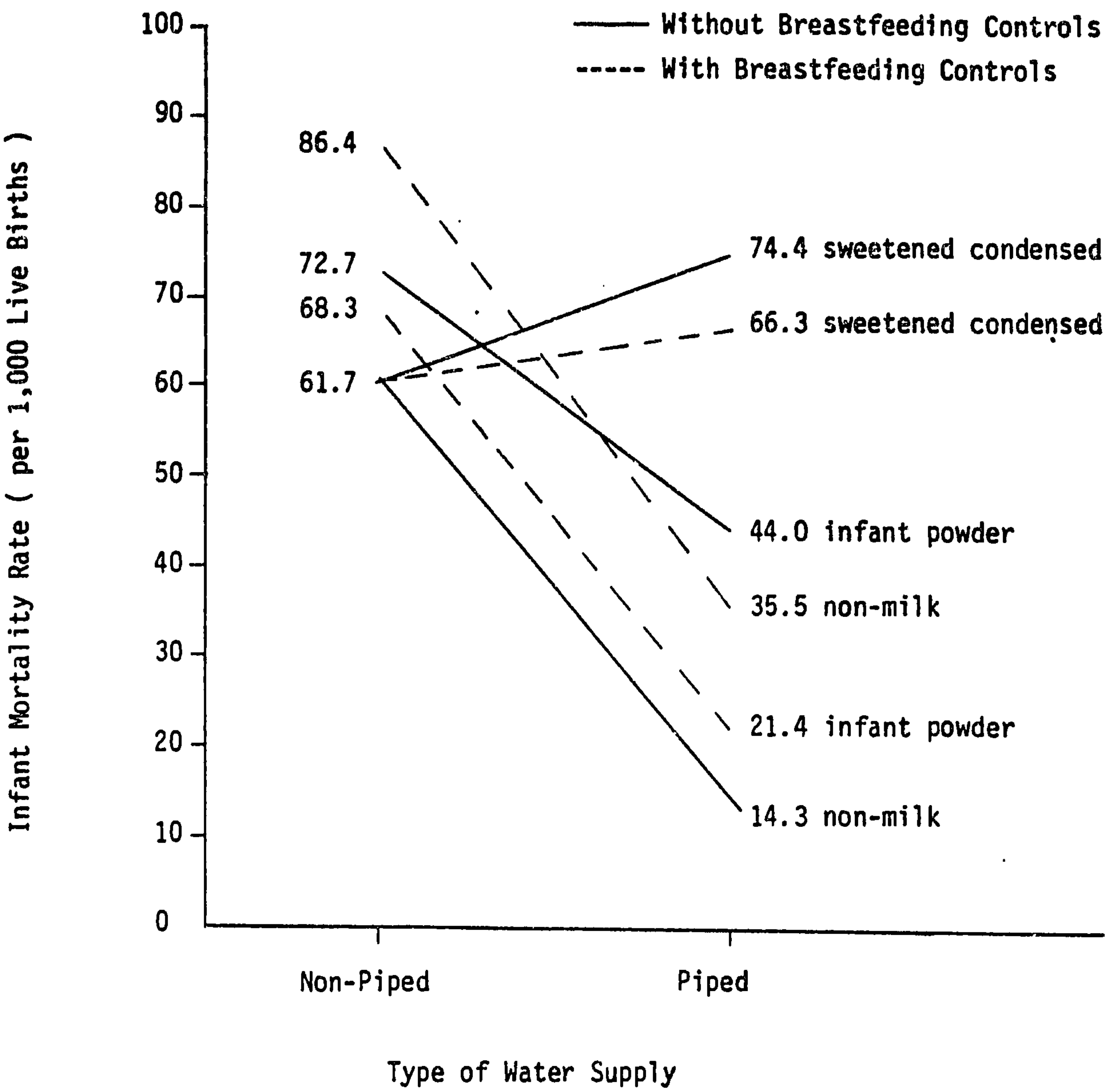

Figure 3a. Infant mortality rates according to water supply and first food introduced other than breast milk for those infants who breastfed at least 4 months.

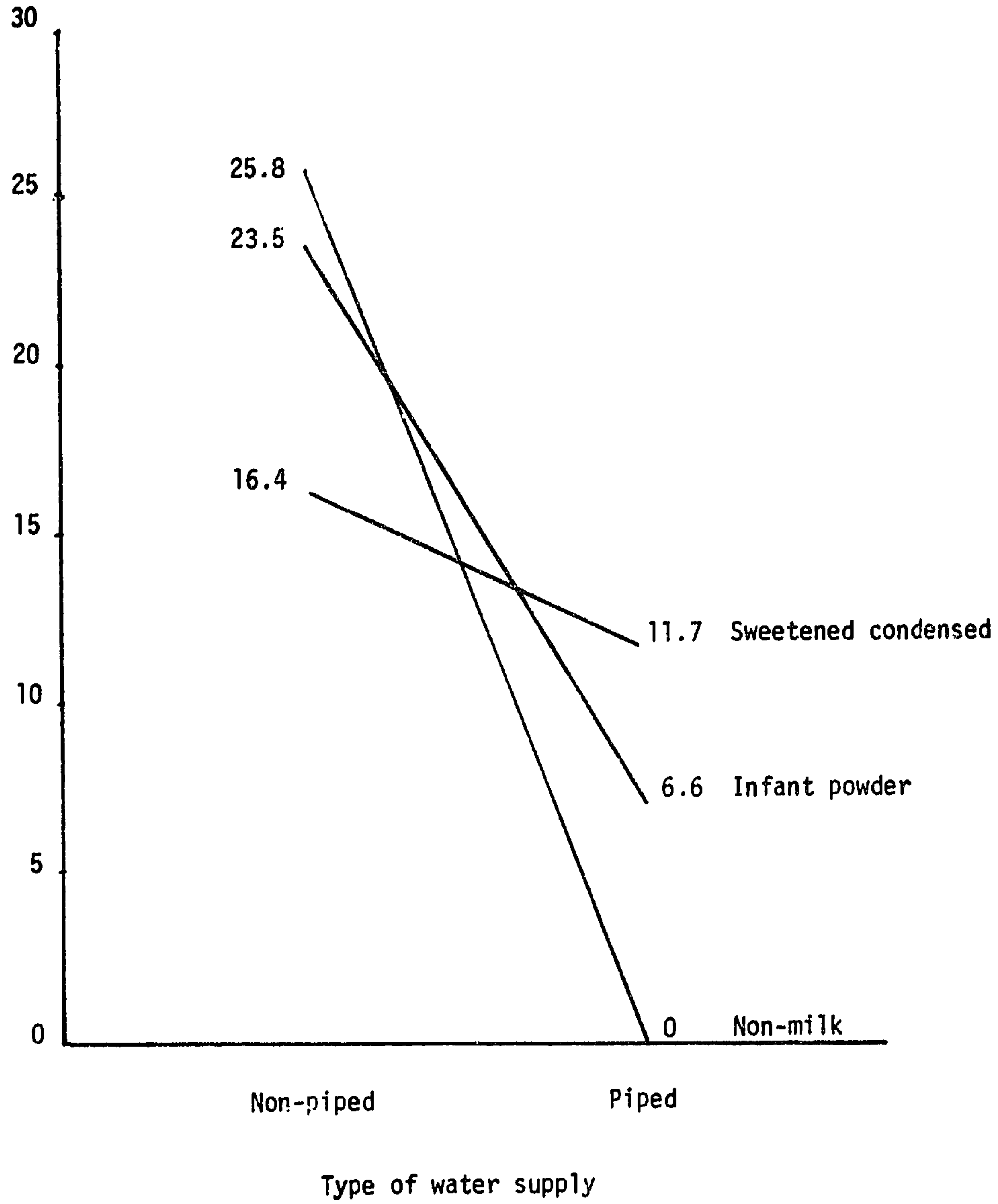

Figure 4. Infant Mortality Rate According to Excreta Disposal Facilities and First Food Introduced Other than Breastmilk

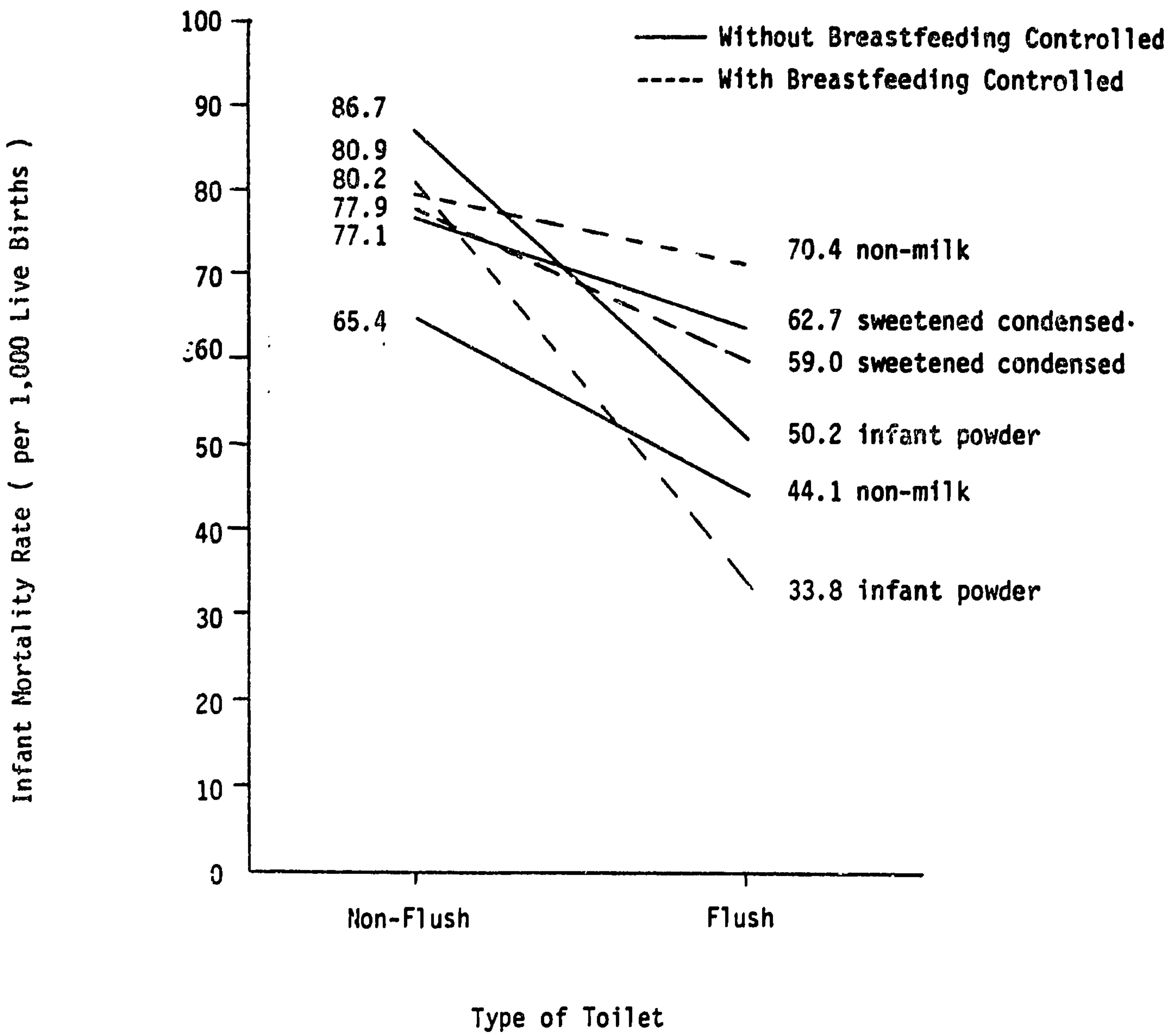

Figure 4a. Infant mortality rates according to excreta disposal facilities and first food introduced other than breast milk for those infants who breastfed at least 4 months