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The Complementary Effect of Latrines and Increased Water Usage on the Growth of Infants in Rural Lesotho

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The effects of water quantity and sanitation, alone and in combination with each other, on infant weight gain and length gain were examined. Data on 119 infants were collected from 20 villages in rural Lesotho between July 1984 and January 1985. The interactions between sanitation and increased water usage for weight gain ($p = 0.007$) and length gain ($p = 0.006$) were significant after potential confounding was controlled. The biggest growth effects were dependent on families possessing a latrine and increasing their use of water during the warm, wet season. Infants gained 1.031 kg (95% confidence interval (CI) 0.420 to 1.642) and 2.028 cm (95% CI 0.523 to 3.533) more when both positive factors were present, as compared with only having a latrine. Increasing water usage compared with not increasing water usage resulted in only 0.105 kg (95% CI −0.175 to 0.385) more weight gain and −0.309 cm (95% CI −1.005 to 0.387) more length in the absence of a latrine. Similarly, infants gained 1.106 kg (95% CI 0.484 to 1.728) and 2.076 cm (95% CI 0.559 to 3.593) more if both factors were operating than did infants whose families only increased their water usage. In the nonincreased water group, the difference in growth between having and not having a latrine was 0.180 kg (95% CI −0.093 to 0.453) and −0.261 cm (95% CI −0.951 to 0.429). Water supply programs should emphasize use of more water for personal hygiene, and sanitation programs should install toilet facilities where water usage is high or has been increased because of an educational program. *Am J Epidemiol* 1992;135:659–66.

anthropometry; growth; infant; sanitation; toilet facilities; water supply

The literature on the health benefits of improvements in water supplies and sanitation is mixed (1). Some of the negative findings are due to improper implementation of the planned intervention, lack of usage of the facilities, and design and measurement problems of the evaluation. It appears that, in better studies, discrepancies between positive and negative findings may be explained by how different interventions are combined (2, 3). Risk factors may complement or compensate for the effects of water and sanitation.

For instance, in Malaysia, toilets and water compensated for a lack of breast feeding (4, 5) and for illiteracy among mothers (6) in reducing infant mortality rates. On the other hand, piped water has complemented the effect of literate mothers in reducing infant mortality rates (6).

Two inferences may be drawn from the above studies. First, interventions to improve sanitation and to increase use of water for better domestic hygiene can improve

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Abbreviations: CI, confidence interval; lcd, liters per capita per day.

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child health, particularly when exposure to the infectious agents of diarrhea is high (7). Second, multiple interventions carried out to reduce exposure to pathogenic agents of diarrhea are more likely to have an impact on health than a single intervention without complementary input (2).

Data from an evaluation of an intervention program designed to improve water supplies in rural Lesotho provide an opportunity to examine the second issue. The impact on child growth from the presence or absence of latrines and from different levels of water usage can be analyzed by testing for a statistical interaction between these two factors. One can hypothesize a priori that as exposure to pathogens is reduced in contaminated areas, children will grow better. Thus, a child's growth will be better among families whose level of both sanitation facilities and per capita usage of water are higher than among other families with inadequate levels of these factors, and will be higher than would be expected given the presence of only sanitation or only high water usage.

Infants exhibit the greatest potential for better growth, because growth faltering usually begins by 4–6 months of age and ceases by 18 months of age (8). Furthermore, it has been reported that water quantity is more important among infants than among older children in Lesotho (9). Thus, only infants will be examined in this paper.

MATERIALS AND METHODS

The infants (n = 119) whose data were analyzed in this report were studied as part of a health impact evaluation of a rural water supply intervention program in Lesotho. These infants, 1–12 months of age at the start of the study, were randomly sampled from 20 rural villages in the lowlands or foothills. The villages were situated in four of the country's 10 administrative districts where 50 percent of the rural population resides. Ten of the villages had access to an improved and functioning community water supply, either taps or hand pumps. The other villages, which relied on traditional sources of water, were selected to be as comparable as possible to the improved villages and were paired with the improved villages with regard to district, village size, and the presence or absence of schools and/or clinics (10). The unimproved villages were also scheduled to receive an improved water supply.

Data were collected in two 5-week periods 6 months apart—July–August 1984 and January–February 1985. During period 1, the cool, dry season, mothers answered questions about socioeconomic characteristics of the household and water usage, and children were measured for length and weight. During period 2, the warm, wet season, children were measured for length and weight, and water usage was measured again. Over 90 percent of the infants were located at follow-up.

Pictures of buckets commonly used to collect water were shown to each mother, who recalled how often each bucket had been filled the previous day. This information was used to determine total household water usage in liters. This figure, divided by the number of household members, was used to estimate the amount of water used in liters per capita per day (lcd). Infants were then categorized into one of three water usage groups: <8 lcd, 8–17 lcd, and >17 lcd. These categories were created because 8 liters represented the average per capita daily water use of the sample and 17 liters represented the amount of water the water project had been designed to provide and represented only two additional 20-liter buckets per family per day above the average. Thus, these categories have public health implications in the Lesotho context.

Infants were then classified further according to the changes in the family's per capita water usage from period 1 to period 2. If the infant's family had moved up one or two classifications (e.g., from <8 lcd to 8–17 lcd or >17 lcd), infants were classified as increased water users. If the classification had dropped or stayed the same, infants were classified into the nonincreased water group.

During the dry season in Lesotho, temperatures often drop below freezing during the evening and night, and during the day, temperatures may only reach 10°C. Bacteria have less chance of surviving and being spread by rain in the dry winter months (period 1) than in the wet summer months (period 2). Diarrhea rates were higher in the warm, wet summer months than at the end of the cool, dry winter months and the beginning of summer. Thus, one can predict that using more water as the summer approached would be of benefit to infant growth. Children were also classified as to whether or not the family owned a latrine.

The outcome variable, infant growth, was calculated by regressing each infant's period 2 length or weight on his/her initial length or weight value. Residuals from these regressions were used as the growth outcomes (11). This removed the influence of factors that affected growth prior to the first measure of length or weight used in this study. Thus, the influence of any confounding variable, whether measured or not, pertains only to the period of growth measured in this study.

The effect of water quality was analyzed previously and was found to have an insignificant effect on infant and child growth (10). This has also been found in other studies (7). Therefore, water quality was not controlled in the analyses below. Children who lived in a village without an improved water supply grew better than their counterparts in improved villages (10). This was controlled in the analyses below.

All analyses, including multiple regression, were carried out using SYSTAT, version 3.0 (12), on a personal computer. We measured and controlled a number of potentially confounding variables in the analyses (table 1) by first estimating a full model. If the 80 percent confidence interval for any regression coefficient included zero, that variable was dropped from further analyses. In this manner, a reduced model was estimated. Only the results from the reduced model are presented below. All confidence intervals are at the 95 percent level and are two-tailed.

RESULTS

Latrines

Twenty-two percent of infants came from families that used simple pit latrines. Unadjusted growth differences showed that children whose families possessed a latrine grew 0.251 cm (95 percent confidence interval (CI) −0.373 to 0.875) more in length and gained 0.177 kg (95 percent CI -0.088 to 0.442) more in weight than children whose families did not have a latrine.

Water quantity

The installation of the improved water supplies did not result in the use of more water on a per capita basis compared with the unimproved group. Inhabitants of both groups of villages, improved and unimproved, averaged 9.6 and 7.8 liters per capita per day during periods 1 and 2, respectively. However, within each type of village, improved or unimproved, people used different amounts of water, reaching a high of 35 liters per capita per day.

The unadjusted association between growth and water usage was stronger during period 2 than during period 1, although the 95 percent confidence intervals included zero. During period 1, length gain (−0.022 cm, 95 percent CI −0.060 to 0.016) and weight gain (−0.002 kg, 95 percent CI −0.018 to 0.014) were associated negatively with each per capita liter increase in daily water usage. The regression coefficients for growth and water usage during period 2 were positive (0.035 cm, 95 percent CI −0.016 to 0.084, and 0.019 kg, 95 percent CI −0.003 to 0.041).

Effect of changes in water usage over the seasons

Nineteen percent of the sample came from the increased water usage group. This group more than doubled their water usage, from an average of 5.7 liters per capita per day during period 1 to 12.7 liters per capita per day during period 2 (table 2). This was true regardless of whether or not a latrine was

TABLE 1. Potentially confounding variables considered in a study of the growth of 119 rural Lesotho infants, by water and latrine usage at the start of the study (July 1984)

Variable	Latrine + increased water usage (n = 4)		Rest of sample (n = 115)	
	Mean	Range*	Mean	Range
Household characteristics				
Increased water usage†	1.00	1–1	0.16	0–1
Presence of latrine†	1.00	1–1	0.19	0–1
Remittances†	1.00	1–1	0.79	0–1
Improved water supply†	0.25	0–1	0.51	0–1
Major expenses‡	4.58	2.1–6.7	4.07	0–9.2
Crowding (no. of people/room)	4.00	2–8	2.70	0.5–8
No. of agricultural tools owned	2.50	2–3	0.90	0–5
No. of major household possessions	7.25	6–8	6.70	1–11
Maternal characteristics				
Literate†	1.00	1–1	0.94	0–1
Farms own land†	0.75	0–1	0.45	0–1
Farms other land†	0.00	0–0	0.25	0–1
Knits/sews†	0.00	0–0	0.09	0–1
Brews beer†	0.50	0–1	0.42	0–1
Pregnant†	0.00	0–1	0.02	0–1
Married†	1.00	1–1	0.86	0–1
Bathes ≥4 times/week†	0.25	0–1	0.22	0–1
Child characteristics				
Birth order	5.00	3–8	3.23	1–9
Breast-fed†	1.00	1–1	0.96	0–1
Male†	0.25	0–1	0.50	0–1
Bottle-fed†	0.50	0–1	0.41	0–1
Age (months)	5.25	2–12	7.49	1–12
Length/age Z score	−1.25	−1.98 to −0.28	−1.44	−5.78 to 2.90
Weight/age Z score	−0.09	−0.60 to 0.77	−0.38	−3.99 to 3.10
Weight/length Z score	1.22	0.06 to 2.14	0.91	−1.13 to 3.36

* Minimum value to maximum value.
† 0 = no, 1 = yes.
‡ Maluti/6 months (January–July 1984) (natural logarithm).

TABLE 2. Changes in per capita water usage over a 6-month period (July 1984–January 1985) in the families of 119 infants in rural Lesotho, by latrine ownership and water usage level

		Latrine ownership: No	Latrine ownership: Yes	Average
Increased water usage	No	10.6* to 6.6† n = 74	10.4 to 6.8 n = 22	10.5 to 6.6
	Yes	5.9 to 12.5 n = 19	5.1 to 13.3 n = 4	5.7 to 12.7
Average		9.6 to 7.8	9.6 to 7.8	

* Liters per capita per day during period 1 (July–August 1984).
† Liters per capita per day during period 2 (January–February 1985).

present. The corresponding figures for the nonincreased water group, which comprised 81 percent of the sample, were 10.5 and 6.6 liters per capita per day, respectively. The decrease was similar regardless of latrine status. In summary, the presence or absence of a latrine in the family was not associated with a change in the per capita usage of water. Unadjusted differences in infant growth between the increased water users and the nonincreased water users were 0.230 cm (95 percent CI −0.423 to 0.883) and 0.317 kg (95 percent CI 0.044 to 0.590).

Complementarity between changes in water usage and latrines

The majority of infants in the sample (62 percent) did not have a latrine in the family and did not increase their water usage from period 1 to period 2; only 3 percent of the sample infants both had a latrine and increased their water usage. One third of the infants in the sample either had a latrine (19 percent) or increased their water usage (16 percent).

Analysis of these four groups indicated a complementary effect between water and sanitation on weight gain (table 3) and length gain (table 4). The effect of having a latrine or of increasing water usage was of benefit only if the other positive factor was also present. This was as true for weight gain as for length gain.

For weight gain (table 3), the interaction of latrines and increased water usage was statistically significant ($p = 0.007$). With a latrine present, the effect of increasing water usage versus not increasing water usage was 1.031 kg in weight gain. In the absence of a latrine, the effect was 0.105 kg. Similarly, the effect of having a latrine became apparent in concert with increasing the amount of water used from period 1 to period 2. Among infants in the increased water group, the effect of having a latrine increased weight gain by 1.106 kg. The weight difference between having and not having a latrine in the nonincreased water usage group was 0.180. Six-month weight gain was more than 1 kg greater if both positive factors were present than if only one or none of the factors were present.

The complementarity between increases in water usage over the seasons and the presence of latrines was also found for infant length gain (table 4). The interaction between latrines and increased water usage was statistically significant at $p = 0.006$. The difference in length gain between infants

TABLE 3. Differences in weight gain (kg) over a 6-month period (July 1984–January 1985) among 119 infants from rural Lesotho, by their families' latrine ownership status and water usage*

		Latrine ownership: No	Latrine ownership: Yes	Difference
Increased water usage	No	−0.088† $n = 74$	0.092 $n = 22$	0.180‡ (−0.093 to 0.453)§
	Yes	0.017 $n = 19$	1.123 $n = 4$	1.106 (0.484 to 1.728)
Difference		0.105‡ (−0.175 to 0.385)§	1.031 (0.420 to 1.642)	

* Variables included in the reduced model were: having a latrine, increased water usage, no. of agricultural tools owned, crowding, maternal literacy, frequency of maternal bathing, maternal marital status, improved water supply, and child's age.

† Six-month residual weight gain (kg).

‡ Difference in weight gain (kg).

§ Numbers in parentheses, 95% confidence interval.

TABLE 4. Differences in length gain (cm) over a 6-month period (July 1984–January 1985) among 119 infants from rural Lesotho, by their families' latrine ownership status and water usage*

		Latrine ownership		
		No	Yes	Difference
Increased water usage	No	0.206† n = 74	−0.055 n = 22	−0.261‡ (−0.951 to 0.429)§
	Yes	−0.103 n = 19	1.973 n = 4	2.076 (0.559 to 3.593)
Difference		−0.309‡ (−1.005 to 0.387)§	2.028 (0.523 to 3.533)	

* Variables included in the reduced model were: having a latrine, increased water usage, no. of agricultural tools owned, crowding, maternal literacy, whether the mother knits/sews, whether the mother brews beer, maternal pregnancy status, frequency of maternal bathing, child's sex, and child's age.

† Six-month residual length gain (cm).

‡ Difference in length gain (cm).

§ Numbers in parentheses, 95% confidence interval.

with and without a latrine in the increased water usage group was 2.076 cm. When water usage was not increased, length gain was greater (0.261 cm) among those who did not have a latrine than among those with a latrine. If no latrine was present, increasing the use of water over the seasons was associated with a smaller gain in length of 0.309 cm compared with not increasing water usage. If a latrine was present, increasing water usage increased length gain 2.028 cm more than if water usage was not increased. Both positive factors occurring together resulted in 2.0 cm more growth than if only one factor was present or both were absent.

DISCUSSION

As predicted by theory (13, 14), the combination of the presence of latrines and the use of more water resulted in better child growth. The presence of latrines and the use of more water complemented each other because the beneficial effect of each factor was realized only in the presence of the other factor.

Latrines can break the transmission of fecal-oral pathogens by not allowing the feces-borne infectious agents to come into contact with the environment. The effectiveness of latrines in reducing diarrhea and improving growth has been reported in Lesotho (15) and elsewhere (7). In the absence of proper disposal of feces, pathogens gain access to the environment and can be ingested from a variety of sources. Using more water for personal and domestic hygiene should reduce the quantity of pathogens ingested and the diarrhea morbidity rates. This was the case for *Giardia lamblia* in Lesotho (16). Thus, it is plausible that the combination of latrines and increased water use resulted in better growth by interrupting and reducing the transmission of pathogens.

The effects and p values from the full model, which included all of the factors listed in "Materials and Methods," were similar to the effects and p values from the reduced model. The interaction was significant in all models. The overall mean square error was lower in the reduced model for both weight gain and length gain, indicating that the reduced model removed multicollinearity between variables.

Anthropometric measurement errors were very small, because enumerators used standardized techniques. Infants were measured twice, and if the average of the measurements did not agree with head and arm circumference measurements, also done in duplicate, the infants were remeasured on the same day. Furthermore, period 2 measurements of children were taken without knowledge of period 1 measurements.

It is unlikely that bias existed in the measurement of water. The enumerators who measured water at the end of the study had no knowledge of water use data that were collected when the study began. In addition, the average daily amount of water used per person in this sample was similar to that reported by others in Lesotho (17, 18). In a previous study (17), total water collection was observed at the source, and mothers reported using about 9 liters per capita per day for domestic uses. A more recent study (18) metered taps and hand pumps and reported an average of 8 lcd in villages similar to those used in this study. One village sampled in this study was also metered at the same time. The daily per capita use of water was estimated to be 10.5 liters by the pictorial method and 10.0 liters by metering. The village was metered for 14 consecutive days. The increase in per capita water usage was similar among those with latrines and those without latrines, suggesting that the presence of a latrine had no bearing on how much water was used.

Because only four children with both positive factors were found, their records were scrutinized for differences with the other children. The mean values and ranges of values for the variables were similar, and few differences were found between these four children and the other 115 children in the sample regarding the socioeconomic variables (table 1). The age of the child is a major determinant of growth, and the age range among the four children was 2–12 months (average = 5.3 months), compared with a range of 1–12 months (average = 7.4 months) for the rest of the sample. The regression analyses provided almost identical results with and without age included, and the results reported above include age in the reduced model.

All four infants in the group with both increases in water usage and latrines were breast-feeding at the start of the study, and 96 percent of the rest of the sample was breast-feeding. Two of the four infants were also bottle-feeding, while 41 percent of the remaining infants were bottle-feeding. Information on the composition of the rest of the diet was not available. However, if the combination of more water and latrines reduced diarrhea or other infections, then the caloric intake of the four infants may have been greater than that of the other infants (19), which would have resulted in better growth. Nevertheless, the possibility that these four infants consumed a diet different from that of the rest of the sample, independently of the results of having a latrine or using more water, cannot be ruled out.

Because the children were not randomized into one of the four cells in the study, the possibility of unknown confounding exists. Many of the factors listed in table 1 serve as proxies for health behavior and wealth. Even after we controlled for these and other known potential confounders, the large differences remained. Thus, it is unlikely that the differences found were due to some inherent characteristic of health or wealth associated with using more water or having a latrine.

Families that used large amounts of water during periods 1 and 2 could have had infants that were categorized as nonincreased water users. This would have the effect of underestimating the differences in growth between the increased and nonincreased water groups. However, statistically significant and biologically important differences in growth were found. These results suggest that using more water during critical periods of pathogen transmission will produce health benefits.

It has been reported recently in Sri Lanka that a point estimate of nutritional status was not related to water or sanitation (20) but was related to diarrhea (21). In the present study, cross-sectional nutritional status, as measured by Z scores, was not significantly different (table 1), but growth was. This suggests that growth may be a better measure of a water and sanitation intervention, which is designed to produce continual health benefits, than is a point estimate of nutritional status.

It has been hypothesized that single interventions to improve health may fail to produce measurable health benefits because the necessary and sufficient conditions, if they are not implemented or present at the same time, may mask the potential benefit of a single intervention (2, 3). Thus, specific interventions to improve health must either be accompanied by complementary interventions or be implemented in an appropriate setting whereby health benefits may be realized.

A strong positive effect on child growth was found between level of water usage and latrines. To our knowledge, this is the first report of such complementarity. Because the results are based on a small number of children, these results need to be replicated with adequate control of confounding. Nevertheless, the results are striking, and they correspond to a priori thinking. Thus, the following recommendations seem warranted. Efforts should be made to encourage people to use more water in Lesotho—1 or 2 additional 20-liter buckets per family per day. Furthermore, the results suggest that efforts to encourage people to use more water should be accompanied by the installation of latrines, because complementarity was found between these factors. In addition, sanitation programs should give priority to installing latrines in areas where water usage is already high or has increased as the result of an educational program.

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