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Drinking Water Source, Diarrheal Morbidity, and Child Growth in Villages with Both Traditional and Improved Water Supplies in Rural Lesotho, Southern Africa

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Abstract: This study examined the growth and morbidity rates of young children in relation to exclusive and non-exclusive use of improved water supplies in rural Lesotho, southern Africa. Data were collected for 247 children 60 months of age and under between July 1984 and February 1985 in 10 villages that had an improved water supply at least one year prior to investigation. Children whose families relied exclusively on the new water supply for their drinking and cooking needs grew 0.438 cm and 235 g more in six months than children whose families supplemented the new water supply with the use of contaminated traditional water for drinking and cooking. The difference in growth was greater among children over 12 months of age at the start of the evaluation than among infants. This may be explained partly by lower rates for *Giardia lamblia,* the most commonly identified pathogen in stools in older children. Among infants, similar rates of *Campylobacter,* the most commonly isolated pathogen among infants, may have prevented larger differences. Results suggest that improved drinking water supplies can benefit preschool children's health after infancy, but only if they are functioning and utilized exclusively for drinking and cooking purposes. (*Am J Public Health* 1988; 78:1451–1455.)

Introduction

The evidence for increased health benefits following improvements in the quality of drinking water is equivocal.[1] Young children in urban areas appear more likely to benefit from improved water supplies than young children in rural areas, perhaps because in urban areas drinking water constitutes a major source of exposure to pathogens, while in rural areas other sources of exposure may be more important.

In a previous study in rural Lesotho, southern Africa, improved water supplies were not associated with less diarrhea.[2] In a more recent health impact evaluation in Lesotho, children from villages that had access to an improved water supply had lower stool isolation rates for *Giardia lamblia* and *Escherichia coli,* but they did not have less overall diarrhea.[3] Growth among children from villages without an improved water supply was better than among children from villages with an improved water supply.[3]

Several factors[1,4] could account for the lack of more positive findings in these and other similar studies. One reason postulated, but never documented, is that the improved water supply was not the only water source used for drinking and cooking purposes. This study estimates the protective effect of exclusive versus non-exclusive use of improved water supplies on the prevalence of pathogens in stools, diarrhea rates, and growth of preschool children who resided in villages that had access to an improved water supply.

Methods

The study was conducted in Lesotho, which is a mountainous kingdom surrounded entirely by the Republic of South Africa. The country ranges in elevation from 1,500 to over 3,400 meters, with the majority of the population in the lowlands under 2,000 meters. Ninety per cent of the population (1.5 million) is rural despite increasing urbanization.

Ten villages were studied from July 1984 to February 1985, all of which received an improved water supply between 1967 and March 1983. They were representative of all the villages that received an improved water supply during this time in terms of size and geographic location. The villages were located in four districts that included 50 per cent of the rural population of Lesotho and were in the lowlands or foothills.

All villagers had access to a continually functioning tap or hand pump for at least one full year prior to data collection. The community taps or hand pumps, each of which served 100 people or less, were dispersed throughout the villages. Gravity fed springs, in which water passed through a silt box, supplied water to the taps. In the flatter areas, bore holes were dug when springs or other surface water was unavailable. Depth of the average bore hole was 50 meters, sometimes exceeding 100 meters. Over 90 per cent of the hand pumps installed are the Moyno pump.

Data used in these analyses were collected in three five-week periods: July–August 1984, the cold and dry season, October–November 1984, and January–February 1985, the warm and wet season. Of the 294 children, 1–60 months of age, enumerated during period one, 258 children were found during period 3 (87.3 per cent). Attrition was similar in both groups. Reasons for attrition were: 13 could not be accounted for, 10 were visiting out of the village, eight migrated to another village, parents of three children refused continuation in the study, and two died (one from each group). Finally, 11 children were dropped from the analyses because they never used an improved water supply, leaving a total of 247 children available for analysis.

During the first and third rounds, mothers were interviewed and children were measured for length and weight. The child's age in months at the start of the study was also taken from clinic cards and verified by use of a local events calendar.

Children were weighed and measured for length according to standard techniques,[5] using a portable CMS weighing

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scale (25 kg × 100 g) and measuring board (130 cm × 1 mm), respectively. Intraobserver (0.005 cm^2 and 0.001 kg^2) and interobserver (0.003 cm^2 and 0.001 kg^2) measurement error rates were small.[6]

In order to estimate growth differences for all 247 children over the six-month period final length or weight for all 247 children was regressed on the initial value,[7–11] and residuals from these regressions were then used as the growth outcome in subsequent analyses. Residual analysis accounts for all the effects that influence a child's body size at the start of the evaluation when examining the determinants of growth that occurred only during the time of the evaluation. Residuals are independent of the initial value and may be positive or negative. The difference in residual values between the exclusive and mixed users reflect differences in six-month growth among children. Results were similar when final body size was used as the outcome, while controlling for initial body size.

During round 2, stool samples were collected from 123 children, and they were examined for bacteria, parasites, and viruses according to standard methods reported elsewhere.[3] During all three rounds mothers were asked to report on the presence or absence of diarrhea in their children in the previous 24 hours. We used the common word "letsollo" in Sesotho, which means "running stomach."

Dummy variables related to use of water and socioeconomic conditions were constructed from the interview data. Children were classified according to whether the family relied exclusively on the improved water supply for their drinking and cooking needs (exclusive users) or supplemented the improved water supply with traditional water sources (mixed users). This information was obtained by interview during round 1. Children were also classified according to the family's per capita use of water drinking rounds 1 and 3. Changes in the quantity of per capita water use between rounds 1 and 3, increased versus decreased water use or no change, were also included in the analyses. Changes in per capita water use was a better predictor of growth than was per capita water use at either round 1 or round 3.[3]

Other potential confounding variables were included in the analyses. The dummy variables were village of residence, remittance from at least one person working in the Republic of South Africa (no, yes), latrines (no, yes), maternal literacy (no, yes), maternal marital status (no, yes), pregnancy (no, yes), frequency of maternal bathing (four or more times per week versus fewer than four), child's sex (male, female), child's age (1–12, 13–24, 25–36, 37–48, 49–60 months), and current breastfeeding (no, yes). Continuous variables were natural log of major household expenditures, number of pieces of agricultural equipment, number of major household possessions, household size, crowding (people/room), and parity. Some factors were kept as continuous variables because they explained more of the growth than if they were categorized.

Statistical analyses were done in SYSTAT, version 3.0,[12] a general linear program for least squares analysis of multivariate data. The child was the unit of analysis, and the variables listed above were included in the multivariate models. Ninety-five per cent confidence intervals were calculated. The effects on weight and length were adjusted for potential confounding by first including all factors above and then by including all factors except the effects due to changes in the amount of water used over seasons. Calculations of nutritional status of children compared to National Center for Health Statistics (NCHS) reference data were done using CASP, a software package from the Centers for Disease Control.[13] Length and weight gain, in separate analyses, were examined by comparing the odds ratio of being in the upper versus lower 25th quartile of growth for mixed and exclusive users.

Results

Of the 247 children, 125 were exclusive users and 122 were mixed users. Most potential confounders were distributed similarly between the two groups (Table 1). Three variables (remittance, maternal literacy, and crowding) were more prevalent among the exclusive users; they all were associated negatively with growth. Breastfeeding was also more common among exclusive users, but this was associated positively with growth only among infants. Frequent maternal bathing and increased water use were more common among mixed users; these factors were associated positively with growth. The percentage of exclusive users within each village was variable, ranging from 17.6 to 90.3.

Weight and length were similar between exclusive and mixed users at the start of the study (Table 2). Because initial body size and growth among children aged one, two, three, and four years was similar, only the combined effects of children 13–60 months of age at the start of the evaluation are reported. Mild malnutrition (low weight-for-age) in both groups was a result of stunting (low height-for-age), not wasting (low weight-for-height). In early infancy children followed the NCHS 50th percentile, but by the end of infancy they were already stunted and had lower weight-for-age

TABLE 1—Means of Potential Confounding Factors among Study Children by Use of Drinking Water

Factors	Exclusive Users (n = 125)	Mixed Users (n = 122)
Village of Residence	%	%
Ha Phoku (350)†	35.3	64.7
Phamistone (500)	17.6	82.4
Letsoare (300)	44.4	55.6
Qalabane (600)	24.0	76.0
Khabos (1500)	31.8	68.2
Matube (700)	82.1	17.9
Makhosi (300)	57.9	42.1
Lebone (700)	25.0	75.0
Mangnaneng (500)	87.5	12.5
Khatleng (350)	90.3	9.7
Household Characteristics		
Agricultural tools (mean of 5 items)	1.4	1.2
Crowding (people/room)	2.8	2.3
Household size	5.7	5.7
Ln household expenses (Maluti)	4.3	4.3
Possessions (mean of 12 items)	7.5	7.0
Remittances (yes)	86.4	79.5
Increase water use (yes)	16.0	22.1
Latrines (yes)	29.6	32.8
Maternal Characteristics		
Literacy (yes)	98.4	91.0
Pregnancy (yes)	16.0	16.4
Bathing (>4 times/week)	17.6	25.4
Married (yes)	86.4	92.6
Parity	3.4	3.5
Child Characteristics		
Age		
1–12 months	26.4	21.3
13–60 months	73.6	78.7
Breastfed (yes)	47.2	36.1
Male	48.8	46.7

†Village population size in parentheses

TABLE 2—Per Cent of NCHS Median Reference among children 1–60 Months of Age at Start of Study by Use of Drinking Water

Children's Age in Months	Exclusive Users: Sample Size	Exclusive Users: NCHS ± SD	Mixed Users: Sample Size	Mixed Users: NCHS ± SD
		Weight for Age		
1–12	33	95.6 ± 13.5	26	95.7 ± 12.2
13–60	92	89.6 ± 9.4	96	88.3 ± 11.8
		Length for Age		
1–12	33	94.4 ± 5.1	26	94.9 ± 3.7
13–60	92	93.7 ± 3.7	96	93.7 ± 4.6
		Weight for Height		
1–12	33	110.4 ± 11.2	26	108.7 ± 9.4
13–60	92	100.4 ± 7.9	96	98.8 ± 8.3

values. Children within 13–60 months of age maintained their growth at about 88–89 per cent of the reference weight-for-age and 93–94 per cent of the reference length-for-age; wasting was not apparent.

Absolute unadjusted growth over the six-month period was similar between groups among the infants, but was greater among exclusive users compared with mixed users among the older children (Table 3). The difference in six-month growth between groups based on absolute growth or residuals was also similar. Only differences in six-month growth residuals between groups are presented below.

The average unadjusted difference in weight gain between exclusive and mixed users was 118 g (Table 4). Among infants, the unadjusted difference was inconsequential, but among children 13–60 months of age, the difference was 156 g. On average exclusive users also grew 0.236 cm more in length than mixed users (Table 5), 0.244 cm more among older children.

After adjustment for confounding, the weight gain of children was better among exclusive users than among mixed users whether or not the effects of changes in water quantity were controlled (Table 4). Exclusive users gained 235 g more than mixed users when changes in water quantity were controlled and 226 g when it was not controlled. The difference in length gain between exclusive and mixed users of the new water supply was 0.438 cm when water quantity was controlled and 0.404 cm when it was not controlled (Table 5). Among older children the effects were somewhat

TABLE 3—Six-month Growth among Children by Age at Start of Study and Use of Drinking Water

Children's Age in Months	Exclusive Users: n	Exclusive Users: Growth ± SD	Mixed Users: n	Mixed Users: Growth ± SD
		Weight (g)		
1–12	33	1.036 ± 0.691	26	1.035 ± 0.355
13–60	92	0.817 ± 0.456	96	0.668 ± 0.514
		Length (cm)		
1–12	33	6.464 ± 2.093	26	6.338 ± 1.413
13–60	92	4.239 ± 1.149	96	3.949 ± 1.215

TABLE 4—Differences in Six-Month Weight Gain between Exclusive and Mixed Users of Improved Drinking Water Supplies among 247 Study Children.

Children's Age in months	Weight Differences (g): Unadjusted (95% CI)	Adjusted for Confounding†, Water Quantity: Controlled (95% CI)	Adjusted for Confounding†, Water Quantity: Not Controlled (95% CI)
1–12	1 (−244,246)	1 (−258,260)	24 (−231,279)
13–60	156 (20,292)	293 (114,472)	276 (96,456)
Total	118 (−2,238)	235 (77,394)	226 (66,386)

†All variables listed in the methods section were controlled.

larger for weight and length gain when changes in water quantity were controlled than when it was not controlled; among infants the effects were smaller. When the odds ratio of being in the upper versus lower quartile was examined, mixed users were twice as likely to be in the lowest quartile than exclusive users for both length and weight gain.

In a subsample of 123 children in this study, stool isolation rates were 33 per cent lower for *G. lamblia*, 53 per cent lower for enteropathogenic *E. coli*, and 49 per cent lower for coronavirus-like particles among exclusive users compared with mixed users (Table 6). These pathogens were more common among older than younger children. *Campylobacter* was only slightly less common among infants in the exclusive group compared with the mixed group and *Giardia* was rare in infancy. Rotavirus, *Salmonella* and *Shigella* were not detected. Diarrhea rates were reported to be generally higher among exclusive users than mixed users (Table 7), but differences between groups were small except among infants during round 1.

Discussion

In summary, exclusive use of improved water supplies for drinking and cooking was associated with better child growth, depending on the child's age. Source of drinking water made virtually no difference among infants; among one- to four-year old children, it did affect growth. By extrapolation, the expected improvement in growth over the first five years of life would be 4.4 cm and 2.3 kg.

Comparison groups were similar in that only children from villages with an improved water supply were included in the analyses, thus removing any biases due to systematic differences between villages with and without improved water supplies. Exclusive users still grew less well, however, than children from non-improved villages,[6] even though they grew better than mixed users. Improved and unimproved villages were similar in rurality, village size, presence of schools or clinics, age and sex distribution, and general standard of living. Still, selection bias in the comparison of villages with and without improved water supplies cannot be ruled out, even though virtually all villages applied for a water supply. For instance, water supplies were constructed deliberately in villages that had a recent outbreak of disease.

In the comparison of exclusive and mixed users within villages with improved water supplies, uncontrolled differences may have existed such as distance to the tap or number of people for each tap. Those households nearest to the tap

TABLE 5—Differences in Six-Month Length Gain between Exclusive and Mixed Users of Improved Drinking Water Supplies among 247 Study Children.

Children's Age in months	Length Differences (cm): Unadjusted (95% CI)	Adjusted for Confounding†, Water Quantity: Controlled (95% CI)	Adjusted for Confounding†, Water Quantity: Not Controlled (95% CI)
1–12	0.107 (−0.629, 0.843)	0.083 (−0.576, 0.742)	0.174 (−0.494, 0.842)
13–60	0.244 (−0.103, 0.591)	0.527 (0.072, 0.982)	0.462 (0.000, 0.924)
Total	0.236 (−0.087, 0.559)	0.438 (0.035, 0.841)	0.404 (−0.006, 0.814)

†All variables listed in the methods section were controlled.

TABLE 6—Stool Isolation Rates for Selected Pathogens among Children 1–60 Months of Age at Start of Study by Use of Drinking Water

Pathogen	Exclusive Users n	Exclusive Users Number (%)	Mixed Users n	Mixed Users Number (%)
Campylobacter				
1–12 months	20	5 (25.0)	14	4 (28.6)
13–60 months	40	3 (7.5)	49	0 (0.0)
Escherichia coli				
enteroinvasive				
1–12 months	20	0 (0.0)	14	1 (7.1)
13–60 months	40	1 (2.5)	49	0 (0.0)
enteropathogenic				
1–12 months	20	1 (5.0)	14	2 (14.3)
13–60 months	40	3 (7.5)	49	7 (14.3)
enterotoxigenic				
1–12 months	20	3 (15.0)	14	0 (0.0)
13–60 months	40	3 (7.5)	49	3 (6.1)
Giardia lamblia				
1–12 months	20	1 (5.0)	14	1 (7.1)
13–60 months	40	8 (20.0)	49	13 (27.1)
Coronavirus-like particles				
1–12 months	20	3 (15.0)	14	3 (21.4)
13–60 months	40	10 (25.0)	49	24 (49.0)

or hand pump may have been different from the mixed users in resources or attitudes toward health, allowing them to be exclusive users. For example, these households may have had substantial influence in the village, thereby securing not only the power to determine where the new supplies were located but also the ability to mobilize limited resources that also fostered better child growth. Energy intakes between exclusive and mixed users also were not controlled and cannot be ruled out as a potential confounding effect.

TABLE 7—Diarrhea Rates among Children 1–60 Months of Age at the Start of the Study by Use of Drinking Water

Children's Age in months	Exclusive Users n	Exclusive Users Number (%)	Mixed Users n	Mixed Users Number (%)
Period 1				
1–12	33	4 (12.1)	26	0 (0.0)
13–60	92	8 (8.7)	96	4 (4.2)
Period 2				
1–12	29	4 (13.8)	19	3 (15.8)
13–60	81	5 (6.2)	74	3 (4.1)
Period 3				
1–12	33	8 (24.2)	25	4 (16.0)
13–60	87	5 (5.7)	90	3 (3.3)

The classification of exclusive versus mixed users was done by maternal reporting, not by observation. No incentive was apparent for mothers to report mixed use if they were in fact strictly exclusive users. On the other hand, mixed users may have reported exclusive use since engineers told villagers that the improved water supply should be used solely for drinking and cooking purposes and not for domestic hygiene. If such misclassification did exist, the differences reported above would be underestimated.

Improved water supplies were continually functioning and available for use during the time of the study and for at least one year prior to the study, with three exceptions:

- Prior to data collection one tap from one village had not been working for several weeks. It was reported and fixed prior to data collection.
- Water flow from improved supplies was limited occasionally either because of inadequate source water or because of volunteer restriction from the villagers themselves. In some instances, the taps were shut down for several hours in the middle of the day. Since most water in Lesotho was usually collected during morning and evening hours,[2] the midday closure of these taps probably did not explain differences in patterns of use.
- In another village, one tap was broken for several months and was not fixed. Ten children came from families that lived near this tap and did not use alternative improved water supplies elsewhere in the village. In yet another village, a child was not allowed to use the tap because the family did not contribute with either labor or to a general maintenance fund while receiving the improved water supply. These eleven children were excluded from the analyses because they may have been different from the other children. They gained less in weight but more in length than either the exclusive or mixed users.[6]

Possible reasons for the lack of more positive results among infants was the finding of *Campylobacter* almost solely among infants and the similar isolation rates among both groups. On the other hand, among older children higher isolation rates of *Giardia lamblia*, particularly among mixed users, may have accounted for part of the growth differences between groups. The association between coronavirus-like particles and diarrhea has not been adequately demonstrated, but the lower rate of coronavirus-like particles among exclusive users may have contributed to better growth.

Reported diarrhea rates were actually higher among exclusive users, but reporting was subject to recall bias, defined by the mother, and not verified by clinical examination or observation. The growth variables, on the other hand, were measured with minimal error and not subject to misreporting.

Among infants growth differences between exclusive and mixed users were greater when per capita water use was not included in the analyses and virtually disappeared when water use was controlled, suggesting that among infants, use of water for cleanliness is probably more important than is clean drinking water, probably because virtually all infants were breastfed. The reverse was true among older children. Water quality may become more important as the protective effect of breastfeeding is removed.[14]

Larger villages tended to have a lower percentage of exclusive users than smaller villages. If village size, number of people per tap, or distance to taps was large, continued use of contaminated supplies may have occurred. The installation of more taps closer to individual homes might perhaps avoid the use of contaminated supplies and foster the exclusive use of the improved water supplies for drinking and cooking purposes.

Previous reports in Lesotho[2,3] indicate that improved water supplies must be coupled with health education to encourage people to use only the improved water supplies for drinking and cooking purposes. These supplies must also be maintained to ensure continual functioning, a crucial requirement often missing in water supply projects. Future studies of health impacts from improved water supplies should measure factors affecting water use such as distance to tap, number of families per tap, and reliability of the operation of the new or improved water supplies.

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