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Can improvements in water supply reduce childhood diarrhoea?

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The effects of improving the water supply on the incidence of diarrhoea in 1096 children from three neighbouring villages of the Kirotshe rural health district, Northern Kivu, Zaire were investigated. Two of these villages had piped water, while the third village had no such facility. Children aged under four years on registration were visited fortnightly for one year. Median diarrhoea incidence per two weeks proved to be significantly lower in the two intervention villages than in the control village. In the two intervention villages, median diarrhoea incidence per two weeks was halved in children who lived in households located less than a five-minute walk from the public standpipe, or in households using more than 50 litres of water a day. The association between diarrhoea incidence and facility use did not differ after stratification by socioeconomic variables.

These findings underscore the fact that children in households that use standpipes are exposed to a lower risk of diarrhoea. Therefore, it is important to stress that those in charge of the planning and implementation of water supply interventions investigate the access to, and use of, water amongst the target population.

Introduction

Many clinical and non-clinical interventions are potentially useful in diarrhoea control.[1,2] The systematic study of the health benefits of these interventions, initiated by the Diarrhoeal Diseases Control (CDD) Programme of the World Health Organization (WHO), is still underway.[3,4] However, water supply improvement is a non-clinical intervention which provides reasonably strong evidence of its beneficial impact, even if this evidence has been questioned because of methodological problems.[4-9]

A critical issue in analysing the impact of water supply on the incidence of diarrhoea is to examine the relationship between impact and local conditions (that is, exposure to pathogens, type and availability of water facilities, personal and community health-related behaviour).[6,9] Impact depends on local circumstances and can be strikingly different from place to place. The purpose of this paper is to examine whether a water supply intervention currently carried out in a Zairean rural area has achieved a statistically significant reduction in the incidence of childhood diarrhoea, and whether this reduction is related to the water-use of the targeted population.

Subjects and methods

Study area

The rural health district of Kirotshe stretches along the Kivu lakeshore in the Northern Kivu Province of Zaire. It covers 1600 km^2 with some 220000 inhabitants. Most of the people live by subsistence farming and endure poor socioeconomic conditions.[10,11] Diarrhoea is a leading cause of sickness and death in children in Kirotshe, as it is throughout the Kivu Highlands.[12-14]

Study design

Since 1985, the national rural water supply service and the health managers of the district, with

the collaboration of the United States Agency for International Development (USAID) and the United Nations Children's Fund (UNICEF), have been making sustained efforts to implement a piped water network (public standpipes) to increase the availability of safe water to rural communities.

In 1987, the authors performed a one-year follow-up study in threee neighbouring villages of the district. Two of these villages had piped water, the third village had no such facility at that time and served as an external control. After taking a population census, a systematic sample of approximately 450 households was taken in each of the three villages (20% of the households). All children under four years of age in these households were enrolled in the study (n = 1096).

After collection of baseline information on the day of registration, 15 trained workers conducted fortnightly interviews (24 follow-up visits). A two-week recall period was chosen as the best compromise between scientific requirements and operational feasibility.[6,9,15] Data was collected by proxy reporting (by interviewing mothers at home), and in the field (by means of cross-interviews). The quality of the information was checked fortnightly by a supervision team.

A diarrhoea episode was defined as the passage of three or more liquid stools a day, for three or more days, in one two-week recall period. The answers recorded were simply 'yes' or 'no' to the question: 'Since the preceding visit, did the child pass at least three liquid stools a day during at least three days?' We calculated diarrhoea incidence per-two-weeks per-child by dividing the number of episodes by the amount of child-time of follow-up. This expresses the likelihood of a child being an incident case of diarrhoea in one two-week period. It is worth noting that this method of surveillance which does not distinguish starting and continuing episodes probably either underestimates diarrhoea incidence in children presenting more than one episode during one two-week recall period, or overestimates diarrhoea incidence in children with chronic episodes extending through 14-day periods. We assume that this lack of precision is balanced over the year of follow-up. In addition, interviewers recorded the occurrence of diarrhoea in children on the day of recall (point prevalence).

Subjective information on facility use (such as: 'Do you use the public standpipe?', or 'Where do you draw water from?') was considered unreliable. Because of the social value attributed to 'good' answers, many people might be led to state untruthfully that they were public standpipe users. Therefore, efforts were made to collect objective information on facility use in the two intervention villages. On the one hand, the distance from each household to the nearest standpipe was repeatedly measured (walking distance expressed in minutes) and averaged, for distance was assumed to be related to facility use. On the other hand, the volume of piped water drawn during the preceding day was recorded at each follow-up visit. Since most people were used to collecting drinking water in 22-litre oil cans that were stored in a cool place at home, it was easy to get a rough estimation of the water drawn on the day of recall by counting the cans. These repeated estimations were averaged to obtain a point estimate of the quantity of drinking water drawn per day, in each household.

Statistical analysis

Associations between outcome (diarrhoea incidence) and exposure (facility use) were tested using the Chi-square test or nonparametric techniques. The Mantel-Haenszel test for stratified analysis, and hierarchical log-linear analysis were used as methods of testing for overall association.

Results

Of the 1096 subjects surveyed over the one-year period, 63 (5.7%) died; 127 (11.6%) were lost to follow-up; and 906 (82.7%) completed the study.

Diarrhoea incidence per two-week period proved not to be normally distributed (Kolmogorov-Smirnov goodness of fit test, $p<0.001$). The median diarrhoea incidence per two weeks in children who had died was 0.149 (range 0.000–0.889). The median was 0.063 (range 0.000–1.000) and 0.087 (range 0.000–0.722) in children who were lost to follow-up and in children who completed the study, respectively. Diarrhoea incidence was significantly higher in the group of children who had died than in both other groups (Kruskal–Wallis analysis of variance, p = 0.004; nonparametric multiple comparison test, p<0.05). After stratification for socioeconomic variables, the children who had died also demonstrated a lower maternal education level and a poorer housing quality than the children in both other groups. In these two other groups, however, median diarrhoea incidence and socioeconomic status were not significantly different. Therefore, further analyses were carried out on the subset of 906 survivors who did complete the follow-up. Where appropriate, those children were ranked into three ordered categories according to tertiles of diarrhoea incidence (first tertile n = 305 (33.7%), range 0.000–0.044; second tertile n = 299 (33.0%), range 0.045–0.133; third tertile n = 302 (33.2%), range 0.134–0.722). The children in the first tertile were considered 'healthy' whereas those in the third tertile were labelled 'diseased'.

Median diarrhoea incidence per two-week period was significantly different in the three villages studied (Kruskal-Wallis analysis of variance, p = 0.007), and proved to be significantly lower in both the two intervention villages (0.084 and 0.088) than in the control village (0.091) (nonparametric multiple comparison test, p<0.05).

Even more remarkable was the demonstration of the relationships between diarrhoea incidence and facility use. In the two intervention villages, diarrhoea incidence per two weeks was investigated by computing medians and examining histograms relating incidence to water facility use (Figures 1 and 2). With distance greater than a five-minute walk from household to standpipe, a sharp increase in diarrhoea incidence and a decrease in utilization of piped water was observed. With shorter distances from household to standpipe, the use of piped water rose to 50 litres per household per day, and there was an abrupt decrease in diarrhoea incidence. These cut-off points delimited approximately the left hand tail of the distance distribution – 38.2% of subjects lived further away than a five-minute walk (Figure 1), and the right hand tail of the quantity distribution – 35.1% were drawing 50 litres or more per day (Figure 2).

Sampled subjects could therefore be classified into three groups: no intervention, intervention without facility use, and intervention with facility use. Controls and facility non-users were labelled 'exposed', and facility users were labelled 'non-exposed'. We observed a very significant association between diarrhoea incidence per two weeks and either household-to-standpipe distance (Chi-square test statistic = 63.45, 4 d.f., p<0.001) or quantity of piped water drawn per household per day (Chi-square test = 31.74, 4 d.f., p<0.001). In the non-exposed group, fewer children entered into the third tertile of diarrhoea incidence than in both other groups (Table 1).

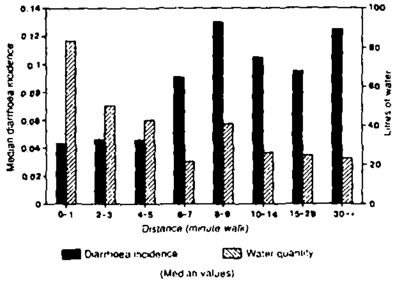

Figure 1. Diarrhoea incidence per two weeks and water use per houshold-day, by household-to-standpipe distance

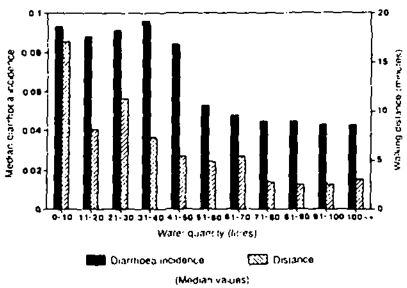

Figure 2. Diarrhoea incidence per two weeks and household-to-standpipe distance, by quantity of water used

Diarrhoea incidence was strongly associated with age (age on the day of registration), but facility use was not (Table 2). More strikingly, diarrhoea incidence and facility use were both associated –the former negatively, the latter positively –with maternal education level, housing quality (a compound index made of three items), and household size (Table 2). No significant associations were found with other potential confounders (professional activity, household income, land tenure, tools ownership, or means of transport).

For stratified analysis, data were ordered in fourfold tables according to exposure status (facility-users versus controls and facility non-users) and disease status (first tertile of diarrhoea incidence versus second and third tertiles), and crude risk-ratios were computed. After stratification on each of the three associated variables, computation of the Mantel–Haenszel test appeared appropriate because of proven homogeneity of relative risks between strata (p>0.05). Compared with the non-exposed, those exposed were more or less twice as likely to be incident cases of diarrhoea. Almost no effects towards the null hypothesis appeared after stratum-specific estimates. Interval estimates were narrow and started far from 1. The overall association between diarrhoea and facility use proved to be fairly robust (Tables 3 and 4).

Multiple relations among outcome variables, exposure variables and potential confounders, were also analysed by hierarchical log-linear modelling. Seeing that a model with only first-order and second-order interaction effects best fitted in with the data, analysis concluded in favour of the mutual independence of pairs of variables, given the level of the others. This implied that the association between diarrhoea and facility use did not differ for maternal education level, housing quality or household size.

Table 1. Diarrhoea incidence, distance to water standpipe, and household water use

	n	Incidence of diarrhoea median	Incidence of diarrhoea range	Subjects in highest tertile %
Study areas				
Total	906	0.087	0.000–0.722	33.3
Control area	368	0.091	0.000–0.708	45.7
Intervention areas	538	0.086	0.000–0.722	30.4
Intervention areas				
Household-to-standpipe distance				
>5 minutes walk	332	0.106	0.000–0.722	41.9
≤5 minutes walk	206	0.044	0.000–0.273	12.1
Water use per household				
<50 litres a day	349	0.091	0.000–0.722	37.0
≥50 litres a day	189	0.045	0.000–0.412	19.5

Discussion

Methodological issues of the study

Comprehensive reviews of methodological issues in impact evaluation of water supply interventions have recently been published.[6,8,9] These reviews discussed several key questions, the following which were addressed in this study: Which study design should be used? What would be the likelihood of potential biases in classification for either disease status or exposure status? How could biases due to confounding be avoided?

Although it has been argued that case-control studies offer an opportunity for rapid, low-cost and valid assessment of water supply impact,[9] we designed a more classical concurrent cohort study for obvious practical reasons. Retrospective enquiry from disease to exposure and case-control matching did not appear feasible in the Kirotshe context because of the poor quality of routine information collected through a scattered network of diarrhoea clinics. On the contrary, forward enquiry from exposure to disease and registration of diarrhoea incident cases by trained health workers, even during a long-term follow-up, suited the local conditions better.

Table 2. Diarrhoea incidence and water facility use by subjects' characteristics

Characteristics of subjects	n	Incidence of diarrhoea highest tertile ≥0.134 % of subjects	p	Distance to standpipe >5 minutes walking % of subjects	p	Household water use ≥50 litres a day % of subjects	p
Sex							
male	455	33.8		23.7		21.5	
female	451	32.8	NS	21.7	NS	20.2	NS
Age at admission							
<1 year	289	52.6		22.1		19.0	
1-<2 years	203	35.5		22.2		22.2	
2-<3 years	210	24.3		22.9		21.9	
3-<4 years	203	13.3	<0.01	23.6	NS	20.7	NS
(mv)	1						
Father's education							
no school	288	38.5		14.9		9.4	
<6 years	260	31.5		16.2		18.1	
≥6 years	312	30.1	NS	35.3	<0.01	32.1	<0.01
(mv)	46						
Mother's education							
no school	636	34.9		14.8		11.9	
<6 years	158	35.4		34.2		31.6	
≥6 years	107	21.5	<0.05	53.3	<0.01	57.0	<0.01
(mv)	5						
Housing quality							
traditional	715	37.3		17.2		13.8	
modern	138	19.6	<0.01	50.0	<0.01	58.7	<0.01
(mv)	53						
Household size							
1-4 persons	274	38.3		19.7		11.3	
5-7 persons	324	33.0		18.2		13.3	
>7 persons	308	29.2	<0.01	30.2	<0.01	37.3	<0.01

p = probability associated with the Chi-square test
mv = missing values.

And, in fact, its successful completion demonstrated the feasibility of such an observational study.

*In designing the study, the validity of diarrhoea-*reporting by proxy could be assumed because no quantitative information (exact number of episodes or numbers of days with diarrhoea) which would have been unreliable anyway, was collected; instead, a restrictive operational definition of diarrhoea was used throughout the survey. 'Diarrhoea' was not a vaguely defined symptom, but a nosologic syndrome depicted without ambiguity. In analysing the data, validity was assessed by examining whether reported *diarrhoea incidence was consistent with observed* diarrhoea prevalence, although perfect concordance was not expected because an incident case could have recovered by the day of recall. The annual number of days of diarrhoea per child estimated from two-week incidence (median diarrhoea incidence × minimal duration of a

Table 3. Relative risk of diarrhoea by distance to water standpipe

	Control vs Distance ≤5 minutes walk RR	95 % CI	p	Distance >5 minutes walk vs Distance ≤5 minutes walk RR	95 % CI	p
Crude risk ratio						
1/2	1.27	1.03-1.57	<0.05	1.29	1.04-1.60	<0.05
1/3	2.93	2.02-4.24	<0.001	3.18	2.20-4.59	<0.001
Mantel-Haenszel relative risk weighted for maternal educational level						
1/2	1.23	0.98-1.54	NS	1.29	1.02-1.63	<0.05
1/3	2.76	1.87-4.08	<0.001	3.04	2.10-4.40	<0.001
Mantel-Haenszel relative risk weighted for housing quality						
1/2	1.19	0.94-1.51	NS	1.24	0.98-1.56	NS
1/3	2.40	1.64-3.51	<0.001	2.77	1.93-3.98	<0.001
Mantel-Haenszel relative risk weighted for household size						
1/2	1.26	1.02-1.56	<0.05	1.26	1.02-1.56	<0.05
1/3	2.84	1.98-4.07	<0.001	3.02	2.10-4.33	<0.001

1/2 = first tertile of diarrhoea incidence vs second tertile
1/3 = first tertile of diarrhoea incidence vs third tertile
p = probability associated with the Mantel-Haenszel Chi-square test.

Table 4. Relative risk of diarrhoea by daily water use

	Control vs Water use ≥50 l/day RR	95 % CI	p	Water use <50 l/day vs Water use ≥50 l/day RR	95 % CI	p
Crude risk ratio						
1/2	1.31	1.04-1.64	<0.05	1.31	1.04-1.65	<0.05
1/3	2.03	1.50-2.74	<0.001	2.01	1.48-2.72	<0.001
Mantel-Haenszel relative risk weighted for maternal educational level						
1/2	1.23	0.97-1.57	NS	1.24	0.97-1.57	NS
1/3	1.83	1.33-2.51	<0.001	1.84	1.36-2.50	<0.001
Mantel-Haenszel relative risk weighted for housing quality						
1/2	1.20	0.93-1.56	NS	1.24	0.97-1.60	NS
1/3	1.83	1.28-2.61	<0.001	1.68	1.25-2.58	<0.001
Mantel-Haenszel relative risk weighted for household size						
1/2	1.30	1.03-1.64	<0.05	1.11	0.86-1.43	NS
1/3	1.97	1.45-2.68	<0.001	1.91	1.39-2.64	<0.001

1/2 = first tertile of diarrhoea incidence vs second tertile
1/3 = first tertile of diarrhoea incidence vs third tertile
p = probability associated with the Mantel-Haenszel Chi-square test.

diarrhoea episode = 0.087 × 3 d.) or from one-day prevalence (median diarrhoea prevalence × 365 d. = 0.052 × 365 d.), was 20 and 19 days, respectively. Out of the 302 children in the third tertile of diarrhoea incidence, 189 (62.6%) entered simultaneously into the third tertile of diarrhoea prevalence. In turn, 215 (70.2%) children out of 305 in the first tertile of diarrhoea incidence were observed to have a low diarrhoea prevalence.

Similarly, cross-tabulation of household-to-standpipe distance by drawn-water quantity showed that 57% of the children who were ranked among facility users according to distance (≤5 minutes walk) were from households with a high demand for water (≥50 litres), whereas 78% of children located beyond a five-minute walk were from households with a low demand for water (<50 litres). Perfect concordance was not expected for it could be argued that demand for water was elastic with respect to distance within a certain range. Although these data are not sufficient to quantify precisely the potential biases in each subject's classification, they offer a rough but satisfying estimate of the internal validity of outcome and exposure variables.

Although controlling for all potential confounders would have been an insurmountable task, we tried to control the subject's characteristics that were found to be relevant according to sociocultural observations and preliminary surveys. The experience accumulated from the field during more than ten years, by some members of the study team was helpful in bridging cross-cultural gaps and providing accurate identification of these characteristics. Three variables demonstrated very significant associations with both diarrhoea incidence and facility use. In fact, people who were better-off were the most likely to be well-educated and well-housed. Moreover, due to the relationships between members of the extended family in the Kivu area, people who were better-off were also very often responsible for the largest households. Therefore, maternal education level, housing quality, and household size can be assumed to be indicators of socioeconomic status.

Implications of the study

Our results suggest that the water supply intervention carried out in Kirotshe has achieved a reduction in the incidence of childhood diarrhoea. In the external control group, the median attack rate of diarrhoea in children under 5 years of age was 2.2 episodes per child per year (0.091 × 24). This rate is similar to the estimate reported by Snyder and Merson,[16] reviewing 24 published studies from 18 developing countries. In the intervention groups, this rate was 2.2 episodes per child (0.91 × 24) living further than five minutes walk from the public standpipe, and was reduced to 1 episode per child (0.044 × 24) when this distance was less than five minutes walk.

Similarly, the median attack rate was 2.4 episodes per child (0.106 × 24) in households using less than 50 litres of water a day, and was reduced to 1 episode per child (0.045 × 24) at higher levels of water use. Moreover, despite close associations between socioeconomic variables with both diarrhoea incidence and facility use, computed relative risks are robust and prove independence from potential confounders. At first, these results add nothing to other positive studies,[6,8] but upon closer examination, they provide a model of the way a water supply intervention produces a beneficial impact in a given situation.

The basic assumptions behind water-related interventions are often over-optimistic. There is hardly any evidence that targeted populations automatically become regular users of the new facilities with which they are provided. Supply is a prerequisite for availability, but accessibility is a prerequisite for utilization. This statement is supported by the observation of a threshold effect, when diarrhoea incidence is related to distance from the source of water. Such a threshold effect was also observed in Bengal[17] where the cholera infection rate appeared lower (3.7%) among subjects living less than 50 feet from a tubewell than among subjects living further away (25.3%). Our results also compare favourably with a study from East Africa (White 1972)[8] which noted that people became users of the new facilities only if the traditional water supply was further than 1 km away from the house, so that there was little alternative but to use the modern one.

All this supports the conclusion that a water supply intervention can alter the water-related behaviour of the target population only in so far as it involves some benefits for the well-being of the people. In a traditional rural environment without any transport facilities and where water collection is a daily burden for women and children, the population is more interested in the closest water facilities than in the safest ones. Whatever the distance, a threshold effect for the quantity of piped water per household per day, was also observed, that corresponds to the supply of about 10 litres of water per person, per day (50 litres/mean household size). A similar threshold effect was observed in Ethiopia[18] for quantities greater than 10 litres per person per day, and in Panama[19] in two groups of subjects provided with 7.1 litres or 2.3 litres per person per day, respectively.

Our results also confirm that facility users are exposed to a lower risk of diarrhoea whatever their socioeconomic status. But the question may then be asked: 'Who are the facility non-users?' The observed associations between socioeconomic variables and both diarrhoea incidence and facility use point to a major failure in the Kirotshe water supply intervention. It becomes evident that accessibility to public standpipes is much better for the few, well-educated and best-housed people, than for the many who are poorly educated and poorly housed. It is likely that the same better-off people who are the least exposed to the risk of diarrhoea, are benefiting the most from the water supply intervention. Since, for obvious technical reasons, the water supply network is implemented along the main road where many of the better-off people live, many of the poor people further away are not reached by the water supply. These people are, however, the ones for whom the programme would be most useful.

Conclusion

These results underscore the need to pay particular attention to the local model of interactions between the population and its environment. An intervention will have a beneficial health impact only in so far as it maximizes the use of the new facilities provided. The planning process must deal not only with technical considerations, but also with behavioural ones. It is therefore of critical importance that those in charge of such a programme perform a careful analysis of the water-related behaviour of the target population.[20,21]

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The influence of new maternal care facilities in rural Nigeria

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Intrapartum care was begun in a public sector comprehensive health centre in Obukpa Town, a rural Nigerian community in May 1987. Its influence on the utilization pattern of maternal health care services was studied in a sample of 488 women who underwent an abortion or childbirth between May 1987 and July 1989. There was an increase in utilization of prenatal care facilities in the comprehensive health centre, from 52% in 1987 to 66% in 1989, and a decline in the use of other health facilities from 41% to 31%. Use of the comprehensive health centre for intrapartum care increased from 15% in 1987 to 36% in 1989, while home delivery declined from 60% to 38% in the same period. Use of other health institutions for delivery remained unchanged. Logistic regression analysis showed that place of delivery and attendant at delivery varied significantly with year of delivery. Women were more than twice as likely to deliver in health institutions (OR = 2.216, p = 0.01) and to be attended by trained staff (OR = 2.525, p = 0.003) in 1989 than in 1987.

The cost of service was found to be about the same for the public and private sectors for prenatal care, and marginally lower for intrapartum care at the comprehensive health centre. Service by traditional birth attendants was free or paid for in kind. The use of the comprehensive health centre was shown to decline with increasing distance from a woman's residence, and distance was considered the determining factor in the choice of a private or public health care institution. The implications of these findings for maternal health policy are discussed and recommendations for change are made.

Introduction

At the beginning of the Nigerian Third National Development Plan period in 1975, coverage of the population by health services in Nigeria was estimated at only 35%. Considerable inequities also existed in the urban and rural distribution of facilities. The federal government of Nigeria, in its efforts to improve this situation, embarked upon the provision of a large number of primary health care facilities nationwide, especially for the under-served rural areas (Federal Republic of Nigeria 1978). The strategy of the Nigerian basic health services scheme (later renamed primary health care programme) was based essentially on the adequate geographical distribution of facilities.

Many of these facilities were located in rural communities which had, up until then, been served almost exclusively by traditional practitioners and a few private health sector facilities. Some of these health centres were entrusted to university colleges of medicine and their teaching hospitals, in an attempt to involve the academic elite of the nation in the delivery of primary health care, and also to ensure high quality care in these new institutions. No evaluation of the impact of the new public facilities on the health-care seeking patterns of the communities has been reported.

This paper describes the changes in the service utilization pattern for the maternal health care, especially in intrapartum care, brought about by one of these health centres situated in the town of Obukpa in Anambra State of Nigeria. It investigates the shifts in the patronage pattern for services provided by the comprehensive health centre, the private sector and traditional birth attendants, and analyses the effects of distance on the utilization pattern.

The study of maternal health service utilization was prompted by the relative neglect of the maternal health component of maternal and