EFFECTS OF PIPED WATER SUPPLY ON THE INCIDENCE OF DIARRHEAL DISEASES IN CHILDREN IN SOUTHERN THAILAND

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Abstract. Simple piped water supply (PWS) is increasingly popular in rural areas of southern Thailand where diarrheal diseases are quite common. The current study was carried out in 1990 in the southern part of Thailand to determine whether the use of PWS could significantly reduce the incidence rate of diarrheal diseases among the children under two years of age. A dynamic cohort study started in January 1990 in seven Muslim villages where PWS was installed for some time and there was a mixture of PWS users and non-users in each village. The cohorts comprised 126 and 137 children using and not using PWS, respectively. They were followed up weekly for one year. The crude incidence rates of diarrhea episodes for children using and not using PWS were 2.54 (SE = 0.21) and 3.52 (SE = 0.18) episodes per child-year, respectively ($p < 0.01$). The number of diarrheal attacks in each week was modeled as a Poisson variate using a generalized estimating equation, adjusting for correlation within the child. The analysis was carried out for each village separately and meta-analysis was used to combine these analyses. The rate ratio of PWS, adjusted for concurrent age and season, food supplement and common cold, was 0.74 (95% CI = 0.59 - 0.93), indicating a statistically significant reduction of one quarter. However, the proportion of users decreased with time due to management failure. It was concluded that diarrheal disease in the study area was mild but the incidence rate was high. The effect of PWS on the incidence rate of diarrhea varied with locality. PWS systems in these communities were unstable and needed improvement in management.

INTRODUCTION

WHO's Water and Sanitation Decade, the period during which Thailand was trying to promote safe water supply in rural areas, has come to a close. Since most acute diarrheal disease in children is infectious and spreads mainly by the feco-oral route, and the disease has been one of the most important communicable diseases in Thailand (National Epidemiology Board, 1987), evaluation of the impact of water supply on the incidence rate of diarrheal disease is necessary.

In southern Thailand, the rainy season is long and ground water is abundant. People often drink unboiled water from shallow wells although PWS pumping from artesian well is agreed to be the best way to promote safe drinking water (Chongsuvivatwong and Mo-Suwan, 1990). The present study was conducted to evaluate the impact of PWS on morbidity due to diarrheal diseases in a district where utilization of the system varied. The objective of the study was to compare the incidence rate of diarrheal attacks among children under 2 years of age whose families used and did not use PWS.

MATERIALS AND METHODS

This was a dynamic cohort study conducted for one year in 7 Muslim villages, where PWS had been installed but not all families used it. The villagers live by rice growing, small-scale fishing and seasonal migration for employment. The PWS in this study was small scale. Each system covered 30 to 80 households. The water was pumped from an artesian well up to a tank on a tower and distributed directly via pipelines to the front yards of target houses where a container was used to store the water. Water flow was restricted to a few hours each day. There was neither filtering nor chlorination.

All children under 2 years of age in households with PWS were recruited for the study. Children in the same age groups residing in households without

PWS closest to the supplied area were used as controls. The households were visited and information was collected on environmental conditions, socioeconomic status and child-rearing habits. Age of the study sample was limited to 2 years because of a limitation of resources and the fact that this group has the highest incidence rates of diarrheal attacks (Varavithya and Ramaboot, 1986). As the study went on, there were new infants born and new children immigrated or came back from seasonal migration into the study villages. These children were included in the study. Some of the recruited subjects also moved out from the area and some reached two years of age during the study thus terminating their follow-up. Each study subject contributed to the person-time at risk only during their follow-up.

Baseline data were collected from October to November 1989. A run-in period for follow-up took place in December 1989 and the actual follow-up period was from January to December 1990.

Each child was visited weekly by a team of four full-time research assistants. Information on diarrhea and respiratory infection, utilization of health care, availability of PWS and toilet and child-rearing practice in the preceding week was obtained from observation and interview of the mother. The child was considered to have diarrhea if he or she passed three or more watery/loose stools or one mucous bloody stool in 24 hours. Diarrhea attacks separated by at least 2 days were considered as separate episodes. Due to limited resources, no laboratory investigation was done.

Data management and analysis

The data were checked carefully in the field and brought back to the University for computerization, using a relational database package. Since there was migration into and from the villages, the number of subjects being followed up changed over time. In the analysis, each week of visit of the resident infant was treated as a record. The changing current status of actual age, season, environmental and behavioral factors was also updated continually. In the calculation of incidence rates, the number of days at risk was calculated as the total number of days less days sick during diarrheal attacks.

The number of attacks per week (0, 1 or 2) was initially modelled as an ordinary Poisson variate. The predictor variables included all factors which were significant in the univariate analysis and PWS. To control for correlation within the same child, generalized estimating equations for Poisson regression (Zeger and Liang, 1986) was computed by a statistical package (Gebski *et al*, 1992). This method was carried out separately for each of the villages keeping PWS and other statistically significant risk factors from the ordinary Poisson regression model. Meta-analysis was then carried out by first testing homogeneity of the rate ratios among the seven villages and then computing a weighted average rate ratio and 95% confidence interval, given that there was no strong evidence that the rate ratios were not homogenous. The pooled coefficient for PWS was calculated by weighting the coefficient in each village with the recipocal of its variance. The pooled standard error of the coefficient was calculated as the recipocal square root of the sum of the recipocals of the village-specific variances.

Finally, since a putative risk factor may exert its effect some time prior to the diarrheal attack, the data were reanalysed by Poisson regression, using the exposure status at one week prior to diarrheal status.

RESULTS

Characteristics of the community and the cohort

Agriculture was the main occupation of the family heads (46%) of study households. Approximately 71% of the parents had finished primary school. Most of the houses (67%) were wooden with ceramic tile roofs. Nearly 95% had electricity. About 30 percent kept livestock, most of them (97%) under the floor of the house. Eighty-three percent of mothers in the study families took care of their children. The mean age of the mothers was approximately 26 years in both groups.

The cohort study started with 178 children, 90 having PWS and 88 without PWS. The proportion of children aged 0-< 3, 3-< 6, 6-< 12 and 12-24 months in January 1990 were 24, 20, 32 and 24% respectively. The distribution of age group and gender were not statistically significantly different in PWS and non-PWS groups.

As the study progressed, more subjects who immigrated to the village or came back from seasonal migration entered the study. Altogether over the study period, there were 263 children: 135 boys and 128 girls. Table 1 shows the number of child-weeks by month in

Table 1

Number of child-weeks in each month by the availability of piped water supply in all villages.

Month	Users	Non-users	Total
January	396	409	805
February	330	377	707
March	352	464	816
April	251	490	741
May	314	575	889
June	289	526	815
July	271	533	804
August	265	562	827
September	238	465	703
October	277	494	771
November	257	454	711
December	156	315	471
Total	3,396	5,664	9,060

each group of users. The total number of child-weeks declined in the last few months as more and more children exceeded 2 years of age and left the study. In December, the total number of child-weeks decreased abnormally because of a flood in the study area and the study was thus terminated two weeks before the end of the year. In general, the number of child-weeks of users declined while that of the non-users tended to be stable or to slightly increase with time, indicating attrition of use. An in-depth study revealed that there were problems of management among the PWS committees in most of the village (Chongsuvivatwong and Mo-Suwan, 1993).

Incidence of diarrheal attacks

A total of 9,060 weekly home visits were made to the 263 subjects in the dynamic cohort. Five hundred and thirty-one diarrheal events were recorded among 194 subjects. Among these, 60 subjects suffered one attack, 57 suffered two attacks and 77 suffered three or more (a maximum of 10) attacks.

One child died as a result of diarrhea. One other child died from severe measles.

The incidence rate for all subjects was 3.19 (SE = 0.14) episodes per child-year. The incidence rates of children at concurrent ages of 0- 3, 3-< 6, 6-< 12 and 12-24 months were 6.77, 4.67, 3.16 and 2.14 episodes per child-year respectively. The incidence rates were similar in boys and girls.

As seen in Fig 1, loose stool diarrhea was more common in the dry season. Watery diarrhea was more common in the rainy season, with a peak in October. Mucous bloody diarrhea was scattered throughout the year.

Of 531 episodes, modern medical treatments were used in 34%, no treatment in 34 percent and herbal medicine in 37%. Only 11% used oral rehydration therapy. Among those who received modern medicine, 6% saw a doctor, 16% went to a health center, and the remainder bought medicine from drug stores.

Duration of illness

The median and mean numbers of days of illness per episode were 3 and 4.01. The minimum duration was only one day (38 episodes) and the maximum duration 28 days (1 episode). There were only 7 episodes lasting more than 14 days. The mean total duration of illness per child-year was 12.3 days for all subjects. The mean number of days of illness decreased with age, being 27.6, 19.2, 11.7 and 7.7 per child-year among children aged 0-< 3, 3-< 6, 6-< 12

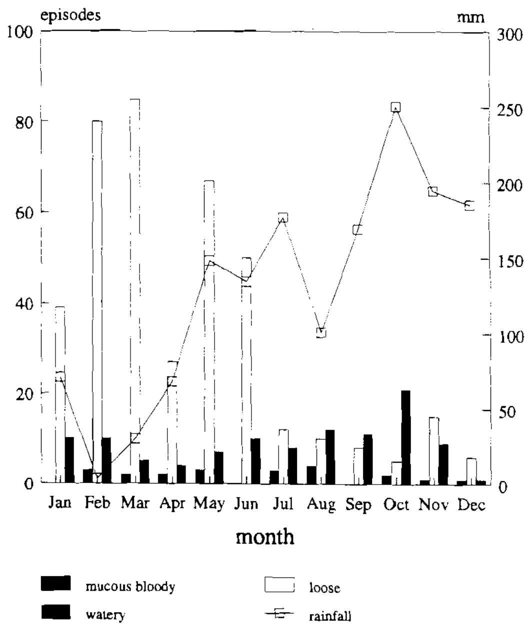

Fig 1–Diarrheal episodes and rainfalls.

and 12-24 months, respectively. The mean durations of illness among boys and girls were similar.

Analysis of the effect of PWS on the risk of diarrhea

In the univariate and multivariate analyses, none of the following variables was a statistically significant risk factor: level of socioeconomic status, (type of housing, level of education and migration history of the parents, and the availability of vehicles and electrical appliances) and variables related to child rearing behavior (hand-washing before feeding, keeping left-over food in the refrigerator). Statistically significant risk factors in the univariate analysis were: village, age group, season, drinking boiled water, breast feeding, food supplement, common colds, availability of toilet and availability of PWS.

The results of ordinary Poisson regression analysis showed that statistically significant factors were: age group, season, village, food supplement and concurrent common cold. Table 2 shows the result of the generalized estimating equations method for Poisson modelling. The village-specific incidence rates and the rate ratios were adjusted for all statistically significant risk factors. The common correlation coefficients within the same child varied around 0.01, indicating that the responses from the same child were approximately independent from one week to another. Of the seven villages, PWS tended to be protective in five (with one being statistically significant) and increase the risk by non-statistically significant amounts in two. The test for a common rate ratio gave a statistically non-significant result. The final weighted average rate ratio was 0.74 (95% CI 0.59 - 0.93).

Table 2

Village-specific adjusted rate ratios of diarrheal diseases (PWS user/non-user) from Poisson regression with generalized estimating equations.

Village No.	Rate ratio (95% CI)*	Estimate of common correlation**
1	0.92 (0.49-1.70)	0.012
2	0.49 (0.20-1.18)	0.015
3	0.46 (0.30-0.71)	0.010
4	1.39 (0.72-2.68)	0.006
5	0.51 (0.19-1.34)	-0.001
6	0.87 (0.55-1.38)	0.008
7	1.06 (0.54-2.07)	0.010

Weighted average 0.74 (0.59-0.93)
Test for homogeneity of rate ratio: chi-squared = 11.66, df = 6, p = 0.07

* Adjusted for age group, season, food supplement and common cold.

** Correlation within the same child using the exchangeable model.

To eliminate doubt on the temporal sequence between the exposure variables and diarrhea episodes, re-analysis using the status of various exposure variables one week prior to the status of diarrhea was undertaken. The results gave a similar conclusion.

DISCUSSION

We found that the incidence rates for diarrheal attacks in our study were higher that those found by other studies conducted in Thailand (Varavithya and Ramaboot, 1986; Sutra *et al*, 1991), but were lower than those found in some developing countries (Black *et al*, 1981; Guerrant *et al*, 1983). In our analysis, days of illness were excluded from days at risk resulting in a smaller denominator than that in a more conventional calculation. However, since the mean number of days of illness per person-year was small compared to total days observation, the difference cannot be attributed to the method of calculation.

The other possible cause of the difference was differing perceptions of villagers regarding diarrhea. In some communities in northeastern Thailand, mild diarrhea is regarded as a normal development of the child and is unlikely to be reported (Thongkajai *et al*, 1993). This was not a problem in the current study since the definition was clarified to the research assistants and the parents.

All of the methodological problems in the analysis of impacts of water supply and sanitation on diarrheal diseases, as reviewed by Blum and Feachem (1983), were carefully dealt with in this study. The control group (PWS non-user) was recruited within the same village as the exposed group. The village factor has also been adjusted for in the model. Concurrent age, seasonality, important behaviors and facility usage, which are missing in many previous studies, were monitored throughout this investigation and controlled for in the analysis. The generalized estimating equation method for Poisson regression controls for intra-subject correlation of response (which is the most fundamental level of correlation) and the separate modelling for different villages followed by meta-analysis takes care of village effects. Thus, this model is more appropriate than the ordinary Poisson model. The correlation coefficients were relatively small but given that the number of repeated observations on the same child is high, ignoring this correlation is likely to give a standard error biased towards zero (Donner and Donald, 1988). In fact, in our initial analyses using ordinary Poisson regression, it was found that the rate ratios in these seven villages were not homogeneous. After taking intra-child correlation into account, the differences became statistically not significant.

The overall rate ratio of 0.74 suggested an overall estimate of one quarter reduction. This level of reduction should be considered as important to public health given that the incidence rates in these communities are relatively high.

The influence of socio-economic factors, latrine usage and other hygienic behaviors was not substantial in this study, partly because they had lower variability and their influences might be masked after adjustment for other stronger determinants.

The fact that availability of PWS varied and tended to fail at the end of the study suggested that there were management or technical problems that needed to be examined and solved. A separate study in the same area revealed that of 67 villages in the district, 31 were installed with one or more PWS and 7 systems were found to have stopped functioning for more than 6 months (Chongsuvivatwong and Mo-Suwan, 1993). The overall failure rate in the country as a whole is not known but this is likely to be a serious problem in further promotion of PWS.

In conclusion, the protective effect of PWS against diarrheal diseases in the study area was significant, both from a statistical and from a public health point of view. Promotion of PWS should be encouraged but improvement of the management is mandatory to ensure sustainability of the program.

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