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Original Article

Assessing the Impact of Community-Led Sanitation Programs on Diarrheal Disease Incidence in Rural Punjab

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ABSTRACT

Background: Childhood diarrhea remains associated with inadequate sanitation, unsafe feces disposal, and poor hygiene in rural Pakistan. Objective: To compare diarrheal incidence and related clinical outcomes among children younger than five years living in rural communities with and without active community-led sanitation programming. Methods: A longitudinal community-based cohort study enrolled 620 households, including 312 in sanitation-program communities and 308 in comparison communities. Baseline child, household, water, sanitation, and hygiene characteristics were recorded, and diarrheal episodes and healthcare outcomes were assessed during follow-up. Incidence was expressed per 100 child-months, and crude group comparisons were calculated from reported data. Results: Seventy-nine diarrheal episodes were recorded in sanitation-program communities and 141 in comparison communities. Reported incidence rates were 2.1 and 3.8 episodes per 100 child-months, respectively, corresponding to an approximate crude incidence-rate ratio of 0.55. Recurrent diarrhea occurred in 5.4% versus 12.7% of children, hospital visits in 7.1% versus 13.3%, intravenous fluid requirements in 3.5% versus 7.8%, and hospital admissions in 2.6% versus 5.5%. Conclusion: Community sanitation-program exposure was associated with lower recorded diarrheal incidence and reduced diarrhea-related healthcare utilization. The observational design and incomplete adjusted analysis precluded causal inference. Keywords: community-led sanitation; diarrhea; under-five children; rural Punjab; WASH; longitudinal cohort; hospital utilization.

INTRODUCTION

Diarrheal disease remains an important cause of preventable morbidity among children younger than five years, particularly in low- and middle-income countries where access to safe water, sanitation, and hygiene services remains inadequate. Repeated diarrheal episodes can lead to dehydration, impaired nutritional intake, growth faltering, increased healthcare utilization, and avoidable childhood mortality. Systematic reviews have shown that interventions targeting unsafe drinking water, inadequate sanitation, and poor hand hygiene can reduce childhood diarrheal morbidity, although the magnitude of benefit varies according to intervention coverage, adherence, environmental conditions, and the level of service achieved (1–3). Recurrent diarrheal illness may also contribute to childhood stunting and other adverse developmental outcomes, particularly where infection and undernutrition occur together (4).

Pakistan continues to experience a substantial burden of diarrhea among children younger than five years. National and regional evidence has demonstrated that diarrheal occurrence is associated with

household poverty, unsafe drinking-water sources, inadequate sanitation facilities, poor hygiene practices, maternal education, household crowding, and other social and environmental disadvantages (5–7). Rural communities may be particularly vulnerable because sanitation infrastructure is frequently incomplete, open drains and standing wastewater remain common, drinking water may become contaminated during collection or storage, and safe disposal of child feces is not consistently practised. These conditions allow several fecal–oral transmission pathways to remain active simultaneously, limiting the effectiveness of clinical treatment alone as a strategy for reducing disease burden (8).

Community-led sanitation programs seek to address these risks by treating sanitation as a collective community responsibility rather than solely as an individual household concern. Such programs commonly involve participatory sanitation mapping, community mobilization, promotion of latrine construction and consistent use, discouragement of open defecation, improved disposal of child feces, handwashing promotion, and continued engagement by local workers or community leaders. Evidence from Mozambique, Ethiopia, and the Democratic Republic of the Congo has shown that community-based sanitation and water, sanitation, and hygiene initiatives can improve latrine ownership, sanitation practices, local participation, and household hygiene conditions (9–11).

Nevertheless, improvements in sanitation infrastructure and behaviour have not consistently produced equivalent reductions in childhood diarrhea. A cluster-randomized trial conducted in rural Mali demonstrated substantial improvements in sanitation access and behaviour but did not identify a comparably large reduction in caregiver-reported diarrhea (12). Subsequent interpretation of major sanitation and integrated WASH trials has suggested that health effects may remain limited when intervention coverage is incomplete, sanitation facilities are inconsistently used, environmental fecal contamination remains widespread, or other transmission pathways are not adequately interrupted (13,14). These findings indicate that the relationship between community sanitation programming and child health is influenced by both program implementation and household-level practices.

Evidence from Pakistan has shown that intensive handwashing promotion and household water treatment can reduce childhood diarrhea in high-risk communities (15–17). However, much of the available local literature has been derived from cross-sectional surveys, hospital records, or studies of care-seeking behaviour rather than longitudinal comparisons of children living in communities with and without active sanitation programming. Qualitative and hospital-based studies have also shown that delayed care seeking, unsafe home practices, environmental exposure, and inappropriate treatment contribute to the clinical burden observed in healthcare facilities (18–20). Longitudinal community follow-up linked with clinical-record verification may therefore provide a more complete assessment of newly occurring diarrheal episodes, recurrence, treatment requirements, and diarrhea-related healthcare use.

The present longitudinal cohort study aimed to compare the incidence of diarrheal disease among children younger than five years living in rural communities with active community-led sanitation programming and children living in comparable communities without structured sanitation programming. Secondary objectives were to compare recurrent diarrhea, diarrhea-related hospital visits, intravenous fluid requirements, and hospital admissions between the two cohorts and to assess whether the association between sanitation-program exposure and diarrheal incidence persisted after adjustment for relevant child, caregiver, water, sanitation, and household characteristics.

MATERIALS AND METHODS

A longitudinal community-based cohort study was conducted among households with children younger than five years living in selected rural communities within the referral catchment area of Ghurki Trust Teaching Hospital, Punjab, Pakistan. The hospital provided clinical support for referred children and served as a source of outpatient, emergency, and admission records for verification of diarrhea-related healthcare encounters when records were available. Rural communities were selected because they

represented settings with a continuing burden of childhood diarrhea and differing levels of organized sanitation activity.

The exposed cohort comprised eligible households residing in communities in which community-led sanitation activities were active during the study period. These activities included community meetings, sanitation mapping, promotion of household latrine construction and use, discouragement of open defecation, handwashing promotion, safer disposal of child feces, and continued community engagement by field workers or local leaders. The comparison cohort comprised eligible households residing in rural communities from the same broad referral setting in which no structured community-led sanitation program was operating during the corresponding period. The comparison communities were selected from settings with broadly comparable socioeconomic and healthcare-access characteristics.

Households were eligible when they were permanently resident in a selected community, included at least one child aged 0–59 months, and had a mother or primary caregiver willing to provide written informed consent and participate in repeated follow-up. Households were excluded when the family intended to leave the community during follow-up, declined repeated contact, or had incomplete baseline information. Children with chronic gastrointestinal disease, severe congenital illness, or another condition expected to alter bowel habits independently of an acute infectious process were excluded.

The sample size was estimated by comparing the anticipated incidence of diarrhea between children living in sanitation-program and comparison communities while allowing for losses during longitudinal follow-up. A multistage sampling approach was used. Rural communities within the hospital catchment area were first classified according to the presence or absence of active community-led sanitation programming. Eligible households were subsequently identified using local household records with assistance from community health workers, and households were enrolled through systematic sampling within the selected communities. A total of 620 eligible households were included, comprising 312 households in sanitation-program communities and 308 households in comparison communities.

The primary exposure was residence in a community with active community-led sanitation programming. Program exposure was assessed at community and household levels. Community-level assessment included the presence of organized sanitation mobilization, participatory meetings, local follow-up, and continued involvement of community workers or leaders. Household-level sanitation conditions were assessed through caregiver interview and direct observation of toilet availability and use, open-defecation practices, availability of a designated handwashing place, presence of soap, disposal of child feces, wastewater disposal, and visible environmental conditions around the household. Households were classified according to community-program exposure for the primary analysis, while individual sanitation and hygiene indicators were evaluated as household characteristics and potential explanatory variables.

The primary outcome was the incidence of new diarrheal episodes among children aged 0–59 months during follow-up. Diarrhea was defined as the passage of three or more loose or liquid stools within a 24-hour period. In exclusively breastfed infants, normally loose stools were not classified as diarrhea unless the caregiver described a clear increase in stool frequency or liquidity accompanied by symptoms of illness. A new episode was recorded when diarrhea occurred following at least three consecutive diarrhea-free days. Secondary outcomes included recurrent diarrhea, defined as two or more episodes during follow-up, diarrhea-related healthcare visits, requirement for intravenous fluid therapy, and hospital admission.

Data collection consisted of baseline household assessment, repeated community follow-up, and clinical-record verification. Trained data collectors administered a structured questionnaire to mothers or primary caregivers at enrollment. Baseline information included the child's age and sex, breastfeeding

status, immunization history, maternal education, household income, household composition, drinking-water source, sanitation facilities, hygiene practices, and recent diarrheal illness. An observation checklist was used to document toilet type and availability, the presence of a functional handwashing place and soap, drainage conditions, standing wastewater, visible animal waste, and household methods for disposing of child feces.

Households were contacted regularly during follow-up. At each contact, caregivers were asked about diarrheal episodes occurring since the previous assessment, episode recurrence, treatment received, use of oral rehydration therapy, healthcare visits, intravenous fluid administration, hospital admission, and changes in household sanitation or hygiene conditions. Community visits were used as the principal method of follow-up. Telephone contact was used when a physical visit could not be completed, with information reviewed at the next available community assessment. Children with symptoms requiring clinical evaluation were referred for routine medical assessment. Where available, outpatient notes, emergency records, and hospital admission records were reviewed to verify diarrhea-related clinical encounters and treatment.

Several procedures were used to improve data quality. The questionnaire and observation checklist were pretested in a rural community with characteristics similar to those of the study setting. Data collectors received standardized training in caregiver interviewing, application of the diarrhea case definition, follow-up documentation, and direct observation of sanitation and hygiene conditions. Completed forms were reviewed for completeness and internal consistency, and a proportion of household assessments was rechecked by field supervisors. Data-entry records were also reviewed to identify missing, duplicate, or inconsistent information before analysis.

The characteristics of the sanitation-program and comparison cohorts were summarized using frequencies and percentages for categorical variables and means with standard deviations for continuous variables. Diarrheal incidence was calculated as the number of newly recorded episodes divided by the accumulated child-time under observation and was expressed as episodes per 100 child-months. Group differences in categorical outcomes were assessed using appropriate tests of proportions, while incidence estimates were compared using incidence-based regression analysis. Multivariable regression analysis was performed to estimate the adjusted association between community-led sanitation exposure and diarrheal incidence. The adjusted analysis considered relevant child-, caregiver-, household-, water-, sanitation-, and hygiene-related characteristics, including child age, maternal education, breastfeeding status, drinking-water source, household toilet availability, handwashing facilities, soap availability, and household crowding. Adjusted incidence rate ratios were reported with 95% confidence intervals. Statistical significance was defined as a two-sided p-value of less than 0.05. Data were analysed using IBM SPSS Statistics version 26.0.

Ethical approval was obtained from the relevant ethical review body of Ghurki Trust Teaching Hospital. Written informed consent was obtained from the mother or primary caregiver before household enrollment. Participation was voluntary, and caregivers could discontinue participation without affecting access to healthcare. Household questionnaires and clinical information were handled confidentially, and study records were used only for research purposes. No invasive research procedures were performed. Children requiring medical assessment or treatment were referred and managed according to routine clinical practice.

RESULTS

A total of 640 households were assessed for eligibility, of which 620 were enrolled in the study. The sanitation-program cohort included 312 households, while the comparison cohort included 308 households. Twenty households were reported as lost during follow-up because of migration, repeated unavailability, or incomplete records. As the distribution of these losses between the two cohorts and the

corresponding final child-level denominators were not available, baseline group denominators were retained for the descriptive analyses.

Table 1. Baseline Characteristics of the Study Cohorts

Characteristic	Sanitation-program cohort (n=312)	Comparison cohort (n=308)
Child age, months, mean ± SD	24.8 ± 13.1	25.2 ± 12.8
Male children, n (%)	163 (52.2)	156 (50.6)
Mothers with at least primary education, n (%)	140 (44.9)	131 (42.5)
Improved drinking-water source, n (%)	182 (58.3)	173 (56.2)
Household toilet available, n (%)	224 (71.8)	151 (49.0)
Functional handwashing place with soap, n (%)	197 (63.1)	119 (38.6)
Open defecation practised, n (%)	39 (12.5)	98 (31.8)
Safe disposal of child feces, n (%)	201 (64.4)	126 (40.9)

SD: standard deviation.

The mean age and sex distribution of children were similar between the cohorts. The proportion of mothers with at least primary education was 44.9% in sanitation-program communities and 42.5% in comparison communities, while access to an improved drinking-water source was reported by 58.3% and 56.2% of households, respectively. Sanitation and hygiene indicators differed more substantially between the groups. Household toilet availability was 71.8% in the sanitation-program cohort compared with 49.0% in the comparison cohort, and a functional handwashing place with soap was observed in 63.1% and 38.6% of households, respectively. Open defecation was reported by 12.5% of sanitation-program households and 31.8% of comparison households. Safe disposal of child feces was also more frequent in sanitation-program communities than in comparison communities, at 64.4% versus 40.9%.

During follow-up, 79 diarrheal episodes were recorded in the sanitation-program cohort and 141 in the comparison cohort. The reported incidence rates were 2.1 and 3.8 episodes per 100 child-months, respectively. On the basis of these reported rates, the crude incidence-rate ratio was approximately 0.55, indicating a lower recorded diarrheal incidence in sanitation-program communities. Because the underlying exact child-time denominators were not available, a confidence interval for this derived rate ratio was not estimated.

Table 2. Diarrheal Incidence and Secondary Clinical Outcomes During Follow-up

Outcome	Sanitation-program cohort (n=312)	Comparison cohort (n=308)	Crude relative measure	p-value
Total diarrheal episodes, n	79	141	—	<0.001
Incidence rate per 100 child-months	2.1	3.8	IRR ≈ 0.55	<0.001
Children with recurrent diarrhea, n (%)	17 (5.4)	39 (12.7)	RR 0.43	0.002
Diarrhea-related hospital visit, n (%)	22 (7.1)	41 (13.3)	RR 0.53	0.011
Intravenous fluid requirement, n (%)	11 (3.5)	24 (7.8)	RR 0.45	0.021
Hospital admission, n (%)	8 (2.6)	17 (5.5)	RR 0.46	0.048

IRR: incidence-rate ratio; RR: risk ratio. Crude RRs were calculated from the reported event counts and baseline group denominators. The approximate IRR was calculated from the reported rounded incidence rates. Because final analysed denominators following attrition were unavailable, these estimates should be interpreted as descriptive crude comparisons.

Children in sanitation-program communities experienced fewer recurrent diarrheal episodes than those in comparison communities. Recurrent diarrhea was reported in 17 children (5.4%) in the sanitation-program cohort and 39 children (12.7%) in the comparison cohort, corresponding to a crude RR of 0.43. Diarrhea-related hospital visits occurred in 22 children (7.1%) and 41 children (13.3%), respectively, yielding a crude RR of 0.53. Intravenous fluid therapy was required by 11 children (3.5%) in sanitation-program communities and 24 children (7.8%) in comparison communities, corresponding to a crude RR of 0.45. Hospital admission was recorded for eight children (2.6%) in the sanitation-program cohort and 17 children (5.5%) in the comparison cohort, with a crude RR of 0.46. Although the reported p-value for admission was below 0.05, the small number of admission events limits the precision of this comparison.

Table 3. Absolute Differences in Diarrhea-Related Child-Level Outcomes

Outcome	Sanitation-program cohort, %	Comparison cohort, %	Absolute difference
Recurrent diarrhea	5.4	12.7	−7.3
Diarrhea-related hospital visit	7.1	13.3	−6.2
Intravenous fluid requirement	3.5	7.8	−4.3
Hospital admission	2.6	5.5	−2.9

Absolute difference was calculated as the percentage in the sanitation-program cohort minus the percentage in the comparison cohort.

The largest absolute difference was observed for recurrent diarrhea, which was 7.3 percentage points lower in sanitation-program communities. Diarrhea-related hospital visits were 6.2 percentage points lower, intravenous fluid requirements were 4.3 percentage points lower, and hospital admissions were 2.9 percentage points lower than in comparison communities. The manuscript reported that diarrheal episodes increased during the warmer and rainy months, particularly from June through September, while remaining lower in sanitation-program communities. However, monthly episode counts and monthly child-time denominators were not available in the reported data. Consequently, no monthly incidence estimates, formal seasonal comparisons, or interaction analyses were presented.

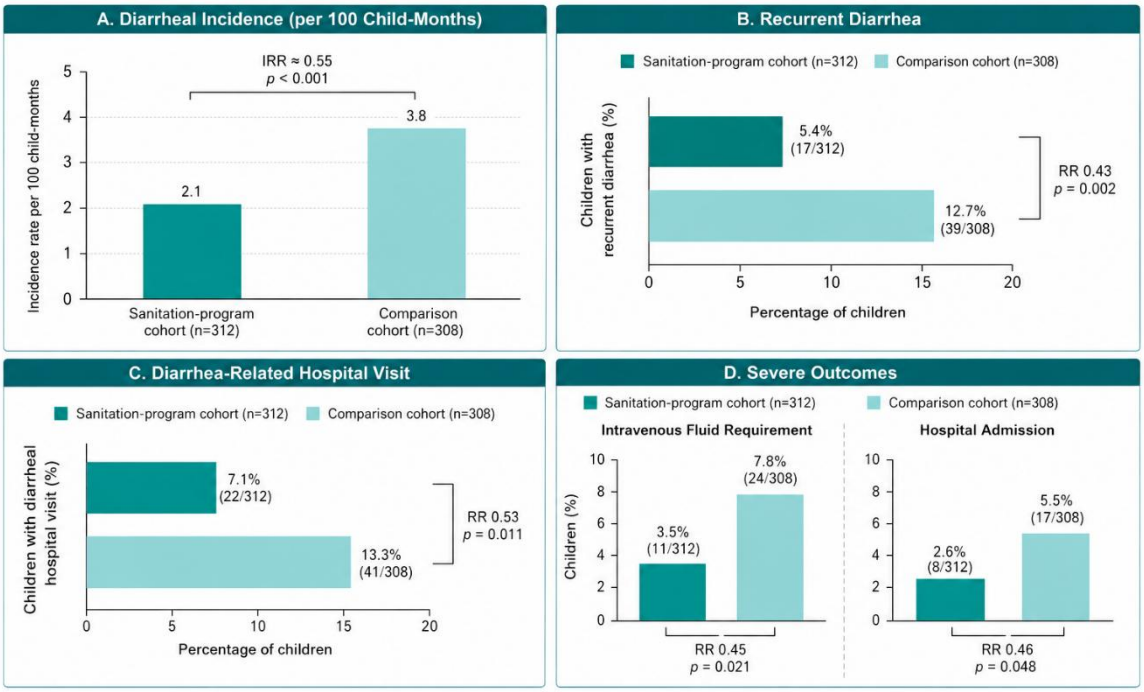

Figure 1. The multipanel figure shows consistently lower diarrheal morbidity among children in sanitation-program communities than in comparison communities, including a lower incidence rate (2.1 vs 3.8 per 100 child-months; IRR ≈ 0.55), recurrent diarrhea (5.4% vs 12.7%; RR 0.43), diarrhea-related hospital visits (7.1% vs 13.3%; RR 0.53), intravenous fluid requirements (3.5% vs 7.8%; RR 0.45), and hospital admissions (2.6% vs 5.5%; RR 0.46), with all reported comparisons reaching statistical significance.

DISCUSSION

The present longitudinal cohort study found that children younger than five years living in rural communities with active community-led sanitation programming experienced a lower recorded burden of diarrheal disease than children living in comparison communities. The sanitation-program cohort had a lower reported incidence rate, fewer recurrent episodes, and lower proportions of diarrhea-related hospital visits, intravenous fluid requirements, and hospital admissions. These findings indicate a consistent association between community sanitation exposure and reduced diarrheal morbidity; however, because communities were not randomly assigned and the adjusted analysis could not be verified, the results should not be interpreted as definitive evidence of causality.

The observed difference in diarrheal incidence was consistent with the broader evidence that improvements in sanitation, safe water, and hand hygiene can interrupt fecal–oral transmission and reduce childhood diarrheal disease. Systematic reviews have reported that WASH interventions are generally associated with lower diarrheal risk, although the magnitude of benefit varies substantially according to the intervention, baseline conditions, implementation quality, adherence, and achieved service level (1–3). The crude incidence rate in the sanitation-program cohort was approximately 45% lower than that in the comparison cohort, based on the reported rates of 2.1 and 3.8 episodes per 100 child-months. This direction of association was compatible with previous evidence but should be interpreted cautiously because exact person-time denominators and cluster-adjusted confidence intervals were unavailable.

The findings also appeared broadly consistent with studies of community-led sanitation and hygiene programs in other low-resource settings. Community-based programs in Mozambique and Ethiopia have improved latrine ownership, use, and sanitation-related behaviour, particularly when community engagement and post-implementation follow-up were sustained (9,10,21). Evidence from the Democratic Republic of the Congo similarly demonstrated that community-driven WASH programs could improve infrastructure, access, behaviour, and local governance (11). Longer-term health effects may depend on whether these improvements are maintained sufficiently to reduce environmental contamination across the community rather than in isolated households (22).

The present findings should also be considered alongside trials that reported limited effects on childhood diarrhea despite improved sanitation behaviour. The cluster-randomized sanitation trial in rural Mali improved access to and use of sanitation facilities but did not demonstrate a comparably large reduction in caregiver-reported diarrhea (12). Interpretation of the WASH Benefits and SHINE trials has likewise suggested that modest household-level interventions may be insufficient when fecal contamination remains widespread and multiple transmission pathways continue to operate (13,23). A sanitation program may therefore improve health only when coverage, use, maintenance, safe feces disposal, hand hygiene, water handling, and wider environmental cleanliness improve together. The baseline pattern in the present cohort supported this interpretation because sanitation-program communities had greater toilet availability, more functional handwashing facilities with soap, less open defecation, and safer disposal of child feces.

The association observed in this study was also compatible with evidence from Pakistan. Randomized studies conducted in high-risk communities in Karachi found that intensive handwashing promotion, with or without household water treatment, reduced childhood diarrheal illness (15–17). Earlier microbiological work also demonstrated that handwashing with soap reduced fecal contamination of hands in a low-income urban community (24). These studies evaluated specific household-level practices rather than community sanitation exposure, but they support the underlying mechanism that interruption of fecal–oral transmission can reduce enteric disease.

The baseline characteristics further indicated that water, sanitation, and hygiene conditions were interrelated. Although access to an improved drinking-water source was similar between the cohorts, sanitation-program households had substantially higher toilet availability and soap-equipped handwashing facilities and substantially lower open defecation. National and regional studies from Pakistan have identified unsafe water, sanitation deficiencies, poverty, low maternal education, household crowding, and other socioeconomic conditions as determinants of childhood diarrhea (5–7,25). Similar associations have been reported in community studies and pooled analyses from Ethiopia and the Democratic Republic of the Congo, where household latrine access and environmental sanitation were associated with lower diarrheal prevalence among children younger than five years (26–28).

The lower proportion of recurrent diarrhea in sanitation-program communities was clinically relevant because repeated episodes may contribute to dehydration, nutritional deterioration, impaired growth, and increased healthcare use. Multicountry evidence has linked cumulative diarrheal burden with

childhood stunting, particularly when repeated infections occur during early life (4). Although nutritional outcomes were not assessed in the present study, the observed absolute difference of 7.3 percentage points in recurrent diarrhea suggests that the association may have implications beyond isolated acute episodes. This interpretation remains provisional because recurrence was based on caregiver-reported episodes and the exact duration of follow-up was not available.

The differences in healthcare utilization also suggested that community environmental conditions may be related not only to the frequency of diarrhea but also to its clinical burden. Diarrhea-related hospital visits, intravenous fluid administration, and admissions were less frequent in sanitation-program communities. Hospital-based studies in Pakistan have shown that children with acute diarrhea may present after delayed care, inappropriate treatment, or progression to dehydration, while socioeconomic and household factors influence disease severity and healthcare utilization (19,20,29). The lower crude proportions of these outcomes in the sanitation-program cohort therefore have potential public-health relevance. Nevertheless, differences in access to care, referral behaviour, distance from the hospital, treatment at other facilities, and record availability could have influenced these comparisons.

The study had several strengths. Its longitudinal design allowed newly reported diarrheal episodes to be recorded over time rather than relying on a single cross-sectional assessment. The inclusion of sanitation-program and comparison communities within the same broad referral setting enabled a practical comparison of communities exposed to different sanitation conditions. Direct observation of household sanitation indicators strengthened exposure characterization, and linkage with available hospital records added clinical information on healthcare use and treatment.

Several limitations materially affected interpretation. First, the observational design was susceptible to selection bias and residual confounding because communities with active sanitation programs may also have differed in leadership, socioeconomic conditions, health awareness, infrastructure, or previous external support. Second, children and households were clustered within villages, but cluster-adjusted estimates were not available. Third, repeated episodes within the same child may not have been statistically independent. Fourth, the number of children, final group-specific denominators, exact person-time, and distribution of attrition were not fully documented. Fifth, caregiver reporting over repeated intervals may have introduced recall and reporting bias. Sixth, exposure was assigned primarily according to community program status, although actual household participation and adoption may have varied. Seventh, toilet availability, handwashing facilities, and related household factors may have acted as mediators of the sanitation program rather than conventional confounders. Eighth, hospital verification was available only for some clinical encounters, and children may have received care at other facilities. Finally, no laboratory confirmation, water-quality testing, nutritional assessment, or verified multivariable model was available.

Future studies should use clearly defined prospective protocols, document the number of eligible children per household, record exact child-time, and report losses separately by exposure group. Analyses should account for clustering within communities and repeated episodes within children, preferably through mixed-effects or generalized estimating-equation models appropriate for count outcomes. Program duration, implementation fidelity, household participation, contamination between communities, and time-varying sanitation practices should also be measured. Where feasible, diarrheal surveillance should be complemented by water-quality testing, laboratory confirmation of enteric pathogens, nutritional assessment, and predefined seasonal analyses.

Overall, the findings provide observational evidence that residence in communities with active sanitation programming was associated with lower recorded diarrheal incidence and reduced diarrhea-related healthcare utilization among children younger than five years in rural Punjab. The consistency of the crude findings across several outcomes supports further evaluation of community-led sanitation as part of integrated child-health and WASH strategies, while the methodological limitations preclude firm causal conclusions.

CONCLUSION

Among children younger than five years living in selected rural communities of Punjab, residence in communities with active community-led sanitation programming was associated with a lower reported incidence of diarrhea, fewer recurrent episodes, and lower proportions of diarrhea-related hospital visits, intravenous fluid requirements, and admissions than residence in comparison communities. Because the study was observational and complete cluster-adjusted and multivariable estimates were unavailable, the findings should be interpreted as supportive rather than causal evidence for sustained community sanitation and hygiene programming.

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