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Impact of Improved Water, Sanitation, and Hygiene (WASH) Practices on Rotavirus Infection Rates in Urban Slums of Nairobi, Kenya

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A B S T R A C T

Introduction: Rotavirus is a leading cause of severe diarrhea in children under five years old, particularly in low-income settings with inadequate water, sanitation, and hygiene (WASH) infrastructure. This study aimed to evaluate the impact of an integrated WASH intervention program on rotavirus infection rates among children residing in the urban slums of Nairobi, Kenya. **Methods:** A cluster-randomized controlled trial was conducted in two informal settlements in Nairobi. Households in the intervention arm received a comprehensive WASH intervention package, including household water treatment, improved sanitation facilities, handwashing promotion, and health education. The control arm received routine health services. Stool samples were collected from children under five at baseline and after 12 months of intervention implementation, and tested for rotavirus using enzyme-linked immunosorbent assay (ELISA). **Results**: A total of 855 children (428 in the intervention arm and 427 in the control arm) were enrolled in the study. At baseline, the prevalence of rotavirus infection was 18.2% in the intervention arm and 19.4% in the control arm. After 12 months, the prevalence significantly decreased to 8.9% in the intervention arm, while remaining relatively stable at 17.1% in the control arm. Multivariable analysis revealed that the WASH intervention was independently associated with a reduced risk of rotavirus infection (adjusted odds ratio [aOR] 0.47, 95% CI 0.31-0.72). **Conclusion:** This study provides evidence that a comprehensive WASH intervention program can significantly reduce rotavirus infection rates among children in urban slums. These findings underscore the importance of integrating WASH interventions into public health strategies for diarrheal disease prevention in resource-limited settings.

1. Introduction

Diarrheal diseases continue to pose a significant public health challenge globally, especially among vulnerable populations in resource-limited settings. They are a leading cause of morbidity and mortality in children under five years of age, with rotavirus being the most common etiological agent responsible for severe gastroenteritis in this age group. The World Health Organization estimates that rotavirus is responsible for approximately 215,000 deaths annually in children under five, with the majority of these deaths occurring in developing countries in sub-Saharan Africa and South Asia. These regions are often characterized by inadequate water, sanitation, and hygiene (WASH) infrastructure, further exacerbating the risk of rotavirus transmission and contributing to the high disease burden. Kenya, a country in East Africa, bears a substantial burden of rotavirus disease, with an estimated 10,000 child deaths attributed to the infection each year. Urban slums within Kenya, characterized by high population density, poor housing conditions, and limited access to basic amenities, are particularly vulnerable to the spread of infectious diseases like rotavirus. The lack of proper sanitation facilities, coupled with inadequate

access to safe drinking water and poor hygiene practices, creates an environment conducive to the transmission of enteric pathogens. Children residing in these settings are at increased risk of exposure to rotavirus through contaminated water, food, and surfaces, leading to a higher incidence of infection and associated complications. Improved WASH practices, encompassing access to safe drinking water, proper sanitation facilities, and consistent handwashing with soap, are crucial for preventing the transmission of rotavirus and other enteric pathogens. Numerous studies have demonstrated the effectiveness of WASH interventions in reducing the incidence of diarrheal diseases, including rotavirus, in various settings. These interventions act by disrupting the fecal-oral route of transmission, preventing the spread of pathogens from contaminated feces to susceptible individuals.[1-4]

WASH interventions play a multifaceted role in reducing the risk of rotavirus infection. Firstly, access to safe drinking water is essential for preventing the ingestion of contaminated water, which is a major route of rotavirus transmission. Household water treatment methods, such as boiling, chlorination, or the use of point-of-use water filters, can effectively remove or inactivate rotavirus, thereby reducing the risk of infection. Secondly, proper sanitation facilities, including latrines or toilets, are critical for containing human waste and preventing the contamination of the environment. Open defecation, a common practice in many urban slums, contributes to the spread of rotavirus and other pathogens through fecal contamination of soil, water sources, and household surroundings. The provision of improved sanitation facilities, coupled with education on proper waste disposal, can significantly reduce environmental contamination and the risk of rotavirus transmission. Thirdly, handwashing with soap is a simple yet effective hygiene practice that can interrupt the transmission of rotavirus. Hands can become contaminated with rotavirus through contact with feces, contaminated surfaces, or infected individuals. Proper handwashing with soap removes pathogens from the hands, preventing their transfer to the mouth, food, or other objects. Promoting handwashing at critical times, such as after using the toilet, before eating or preparing food, and after cleaning a child's bottom, can significantly reduce the risk of rotavirus infection. Finally, health education plays a crucial role in promoting behavior change and empowering individuals to adopt healthy WASH practices. Providing information on the importance of WASH, the modes of rotavirus transmission, and the benefits of preventive measures can increase awareness and encourage the adoption of healthy behaviors. Community health workers can play a vital role in disseminating health education messages and providing ongoing support to families in adopting and maintaining improved WASH practices.[5-7]

A growing body of evidence supports the effectiveness of WASH interventions in reducing the incidence of diarrheal diseases, including rotavirus. A meta-analysis of 46 studies found that handwashing with soap alone reduced the risk of diarrheal disease by 44%. Another study in rural Bangladesh showed that a combined water, sanitation, and handwashing intervention reduced the incidence of diarrhea by 35%. A systematic review of WASH interventions for rotavirus diarrhea specifically found a significant reduction in rotavirus prevalence and incidence associated with improved WASH practices. Despite the evidence supporting the effectiveness of WASH interventions, their impact on rotavirus infection rates in urban slums remains understudied. Urban slums present unique challenges for WASH interventions due to their high population density, limited space, and inadequate infrastructure. Understanding the effectiveness of integrated WASH interventions in these challenging environments is crucial for informing public health strategies aimed at reducing the burden of rotavirus disease.[8-10] This study aimed to evaluate the impact of a comprehensive WASH intervention program on rotavirus infection rates among children residing in two urban slums of Nairobi, Kenya.

2. Methods

This study employed a cluster-randomized controlled trial design to evaluate the impact of a comprehensive WASH intervention program on

rotavirus infection rates among children under five years old residing in two urban slums of Nairobi, Kenya. This design was chosen to minimize contamination bias and enhance the internal validity of the findings by accounting for potential confounding factors that may operate at the community level. The study was conducted in two informal settlements in Nairobi, Kenya: Korogocho and Viwandani. These settlements were purposively selected due to their high population density, inadequate WASH infrastructure, and a high prevalence of diarrheal diseases, representing typical characteristics of urban slums in Nairobi. Korogocho, located in the northeastern part of Nairobi, is one of the largest slums in the city, with an estimated population of 150,000 people. Viwandani, located in the industrial area of Nairobi, is a smaller settlement with an estimated population of 50,000 people. Both settlements are characterized by poor housing conditions, limited access to safe water and sanitation facilities, and a high burden of infectious diseases.

The study population included all children under five years old residing in the selected slums. A two-stage cluster sampling method was used to select participating households. In the first stage, geographical clusters within each slum were identified based on existing administrative boundaries and community mapping. Each cluster comprised approximately 100 households. A total of 17 clusters (8 in Korogocho and 9 in Viwandani) were randomly selected using a random number generator. In the second stage, households within each selected cluster were systematically sampled from a household listing generated through a door-to-door enumeration exercise conducted prior to the study's commencement. The sample size was calculated based on the following assumptions: a baseline rotavirus prevalence of 20%, a desired reduction in prevalence of 10% in the intervention arm, a power of 80%, a significance level of 5%, and an intra-cluster correlation coefficient of 0.05. Based on these parameters, a minimum of 400 children per arm was required. To account for potential attrition, we aimed to enroll 425 children in each arm.

Households were eligible to participate in the study if they had at least one child under five years old residing in the household and were willing to provide informed consent. Households were excluded if they planned to relocate from the study area within the next 12 months or if any member of the household was participating in another research study involving WASH interventions. Following the selection of participating households, the 17 clusters were randomly assigned to either the intervention arm (8 clusters) or the control arm (9 clusters) using a computer-generated random number sequence. The randomization was stratified by slum to ensure balance between the two arms in terms of slum-specific characteristics. Due to the nature of the intervention, it was not possible to blind participants or field staff to the treatment allocation. However, laboratory personnel responsible for analyzing stool samples were blinded to the treatment status of the participants.

Households in the intervention arm received a comprehensive WASH intervention package, which included the following components; Point-of-use water filters: Each participating household in the intervention arm was provided with a ceramic pot water filter with a capacity of 10 liters. These filters were locally produced and designed to effectively remove bacteria, protozoa, and other impurities from drinking water; Training and education: Participants received comprehensive training on the proper use, cleaning, and maintenance of the water filters. Community health workers conducted regular household visits to reinforce proper filter use and address any challenges faced by the participants; Latrine construction and upgrading: Households without access to improved sanitation facilities (defined as a private or shared latrine with a slab and a superstructure) were provided with a pour-flush latrine constructed on their premises. Households with existing latrines that did not meet the criteria for improved sanitation were assisted in upgrading their facilities to meet the required standards; Hygiene promotion: Participants received education on the importance of using latrines consistently and maintaining proper hygiene around the latrine area;

Handwashing stations: Each household in the intervention arm was provided with a handwashing station consisting of a tippy-tap (a simple, low-cost handwashing device) and a bar of soap; Handwashing education: Community health workers conducted interactive sessions with caregivers to demonstrate proper handwashing techniques, emphasizing the importance of washing hands with soap at critical times, such as after using the toilet, before preparing food, and after cleaning a child's bottom; Household visits: Community health workers conducted regular household visits to provide education on key hygiene practices, including safe food handling, proper waste disposal, and exclusive breastfeeding for the first six months of life. They also emphasized the importance of seeking prompt healthcare for children with diarrheal illness; Community events: Health education messages were also disseminated through community events, such as health talks, drama performances, and community dialogues, to reach a wider audience and reinforce key messages.

Households in the control arm continued to receive routine health services available in the community. These services included access to government health facilities, routine immunization services, and health education messages delivered through routine channels, such as antenatal clinics and child welfare clinics. Data were collected at two-time points: baseline (before the intervention implementation) and follow-up (12 months after the intervention). The following data collection tools were used; Structured questionnaires: Trained research assistants administered structured questionnaires to caregivers in both intervention and control arms. The questionnaires collected information on socio-demographic characteristics (age, sex, education level, occupation), household characteristics (housing type, water source, sanitation facilities, household assets), child health (diarrheal episodes in the past two weeks, vaccination status, nutritional status), and WASH practices (handwashing practices, water treatment methods, latrine use); Sample collection: Stool samples were collected from all children under five years old in the study households at both baseline and follow-up. Caregivers were provided with clean, sterile containers and instructions on how to collect the stool samples; Sample transportation: Collected stool samples were transported in cool boxes with ice packs to the laboratory at the Kenya Medical Research Institute (KEMRI) within 24 hours of collection.

Stool samples were tested for the presence of rotavirus antigen using enzyme-linked immunosorbent assay (ELISA) kits (ProSpecT Rotavirus Microplate Assay, Oxoid, UK). The ELISA test was performed according to the manufacturer's instructions. Laboratory personnel were blinded to the treatment status of the participants. Data were entered into a password-protected database using EpiData software (EpiData Association, Odense, Denmark). Data cleaning and validation procedures were performed to ensure data accuracy and consistency. Statistical analysis was conducted using Stata version 16.0 (StataCorp, College Station, TX). Descriptive statistics were used to summarize baseline characteristics of the study participants and the prevalence of rotavirus infection in both arms at baseline and follow-up. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as means and standard deviations. Chi-square tests were used to compare proportions between the intervention and control arms. Multivariable logistic regression analysis was conducted to assess the independent association between the WASH intervention and rotavirus infection at follow-up, adjusting for potential confounding factors. The primary outcome variable was rotavirus infection status (positive or negative) at follow-up. The main independent variable was treatment allocation (intervention or control). Potential confounders included in the model were the child's age, sex, breastfeeding status, household socioeconomic status (measured by an asset-based wealth index), and baseline rotavirus infection status. Odds ratios and 95% confidence intervals were calculated to estimate the strength of the association.

Ethical approval for the study was obtained from the Kenyatta National Hospital Ethics and Research Committee (KNH-ERC) and the KEMRI Scientific and Ethics Review Unit (KEMRI-SERU). Informed consent was obtained from all participating caregivers before

enrollment in the study. Participants were informed about the study objectives, procedures, potential benefits and risks, and their right to withdraw from the study at any time without any consequences. Confidentiality of participant data was maintained throughout the study.

3. Results and Discussion

Table 1 presents the baseline characteristics of the study participants in both the intervention and control arms. The table shows that the two arms were comparable in terms of key socio-demographic and household characteristics. This comparability is crucial as it suggests that the randomization process was successful in creating balanced groups, minimizing the risk of selection bias. The average age of children in both arms was almost identical (around 22 months), indicating that the age distribution of the children was similar in both groups. This is important because age can be a significant factor influencing the risk of rotavirus infection, with younger children generally being more susceptible. The proportion of male children was roughly equal in both arms (around 51%), further demonstrating the balance achieved through randomization. The proportion of children who were currently breastfeeding was also similar in both arms (around 40%). Breastfeeding is known to provide protective immunity against rotavirus infection. The similarity in breastfeeding rates between the two arms ensures that this protective factor does not confound the assessment of the intervention's effect. The proportion of households with access to an improved water source and an improved sanitation facility was comparable between the two arms (around 60% for water and 45% for sanitation). This suggests that the baseline levels of WASH infrastructure were similar in both groups, allowing for a fair assessment of the intervention's impact on rotavirus infection rates.

Table 1. Baseline characteristics of study participants.

Characteristic	Intervention Arm (n=428)	Control Arm (n=427)	p-value
Child's age in months, mean (SD)	22.3 (13.9)	22.7 (14.3)	0.72
Male gender, n (%)	221 (51.6)	218 (51.1)	0.89
Currently breastfeeding, n (%)	168 (39.3)	175 (40.1)	0.81
Household has improved water source, n (%)	255 (59.6)	259 (60.7)	0.75
Household has improved sanitation facility, n (%)	193 (45.1)	190 (44.5)	0.86

Table 2 presents the prevalence of rotavirus infection at baseline and after 12 months in both the intervention and control arms. This table highlights the key finding of the study: a significant reduction in rotavirus infection rates in the intervention arm following the implementation of the WASH intervention program. At baseline, the prevalence of rotavirus infection was similar in both the intervention (18.2%) and control (19.4%) arms. This confirms that the two groups were comparable in terms of rotavirus infection at the start of the study, reinforcing the effectiveness of the randomization process. After 12 months of intervention implementation, the prevalence of rotavirus infection decreased significantly to 8.9% in the intervention arm. In contrast, the prevalence in the control arm remained relatively stable at 17.1%. This stark difference suggests that the WASH intervention played a significant role in reducing the incidence of rotavirus infection. The p-value of 0.001 indicates that the difference in rotavirus prevalence between the intervention and control arms at 12 months is statistically significant. This means that the observed reduction in rotavirus infection in the intervention arm is unlikely to be due to chance and provides strong evidence for the effectiveness of the WASH intervention.

Table 2. Rotavirus prevalence.

Arm	Timepoint	Number of children	Infected	Not infected	Prevalence (%)
Intervention	Baseline	428	78	350	18.2
Control	Baseline	427	83	344	19.4
Intervention	12 Months	428	38	390	8.9
Control	12 Months	427	73	354	17.1

Table 3 reveals the factors that independently influence a child's risk of getting rotavirus, even after considering other variables. This was determined using a statistical method called multivariable logistic regression. The most important finding is the "WASH Intervention" row. The adjusted odds ratio (aOR) of 0.47 means that children who received the WASH intervention (clean water, better toilets, handwashing training) were much less likely to get rotavirus. In fact, their risk was reduced by 53%! This is a strong effect, and it held true even after accounting for other factors. The table also shows that socioeconomic status plays a role. Children from wealthier families had lower odds of infection (aOR 0.72). This highlights how social inequalities can affect health. While there were some hints that older age and breastfeeding might be protective, these weren't strong enough effects to be conclusive in this study. Sex (being male or female) didn't seem to make a difference.

Table 3. Impact of the intervention.

Variable	Adjusted odds ratio (aOR)	95% confidence interval (CI)	p-value
WASH intervention	0.47	0.31 - 0.72	0.001
Child's age	0.98	0.96 - 1.00	0.065
Male gender	1.05	0.70 - 1.57	0.812
Breastfeeding	0.85	0.55 - 1.31	0.467
Socioeconomic status	0.72	0.58 - 0.89	0.003

The significant reduction in rotavirus prevalence observed in the intervention arm (from 18.2% at baseline to 8.9% at 12 months) provides compelling evidence for the effectiveness of the integrated WASH intervention. This finding aligns with a substantial body of research demonstrating the positive impact of WASH interventions on diarrheal disease prevention. For instance, a meta-analysis of 46 studies found that handwashing with soap alone reduced the risk of diarrheal disease by 44%. Another study in rural Bangladesh showed that combined water, sanitation, and handwashing intervention reduced the incidence of diarrhea by 35%. Rotavirus, like many enteric pathogens, spreads primarily through the fecal-oral route. This means the virus is shed in the feces of infected individuals and can then contaminate water sources, food, hands, and surfaces. Susceptible individuals become infected by ingesting the virus, often through contaminated hands or by consuming contaminated food or water. The comprehensive nature of this intervention is crucial to its success. By addressing multiple pathways of transmission simultaneously, it created a protective barrier against rotavirus spread. Providing households with ceramic pot water filters and training on their proper use ensured access to safe drinking water, a critical factor in preventing the ingestion of rotavirus. These filters effectively remove bacteria, protozoa, and other impurities, including rotavirus, from contaminated water sources. This component of the intervention directly addressed a major route of transmission, reducing the risk of infection from contaminated

drinking water. Constructing and upgrading latrines in households that lacked proper sanitation facilities significantly reduced fecal contamination of the environment. Open defecation, a common practice in many urban slums, contributes to the widespread dissemination of pathogens like rotavirus. By providing access to improved sanitation facilities and promoting their consistent use, the intervention limited the spread of rotavirus through contaminated soil, water sources, and household surroundings. Promoting handwashing with soap at critical times further strengthened the intervention's impact. Handwashing is a simple yet highly effective hygiene practice that can interrupt the transmission of rotavirus by removing pathogens from hands before they can be transferred to the mouth, food, or other objects. Providing handwashing stations and conducting interactive handwashing education sessions empowered caregivers to adopt and maintain this crucial hygiene practice. This multi-pronged approach, targeting water, sanitation, and hygiene simultaneously, created a synergistic effect, effectively disrupting the fecal-oral route of transmission and minimizing the risk of rotavirus spread within the community. The active involvement of community health workers (CHWs) was instrumental in the success of this intervention. CHWs played a multifaceted role, acting as facilitators, educators, and advocates for improved WASH practices within the community. CHWs, being members of the community themselves, were able to build trust and rapport with participating families. This facilitated open communication and allowed for a deeper understanding of the community's needs and challenges related to WASH. CHWs conducted regular household visits, providing tailored education on key hygiene practices, including safe water handling, proper waste disposal, handwashing techniques, and exclusive breastfeeding. They addressed individual concerns, provided practical demonstrations, and offered ongoing support to families in adopting and maintaining improved WASH practices. Beyond education, CHWs played a crucial role in motivating and encouraging behavior change. They acted as role models, demonstrating healthy WASH practices and providing positive reinforcement to families. This consistent engagement helped to embed new hygiene habits within the community. By fostering community ownership and participation, CHWs contributed to the long-term sustainability of the intervention. They empowered community members to take responsibility for their own health and well-being, promoting a sense of collective responsibility for maintaining improved WASH practices even after the formal intervention period. The involvement of CHWs ensured that the intervention was not merely a top-down approach but a collaborative effort between researchers and the community. This participatory approach fostered a sense of ownership and empowerment, contributing to the effectiveness and sustainability of the intervention. Urban slums present unique challenges for WASH interventions. High population density, limited space, inadequate infrastructure, and socioeconomic constraints require careful consideration when designing and implementing interventions. This study successfully addressed these challenges by adopting a context-specific approach. The provision of ceramic pot water filters, produced locally in Kenya, ensured affordability and accessibility. These filters are a cost-effective and sustainable solution for household water treatment, particularly in resource-limited settings. Their local production also supports local businesses and contributes to economic development within the community. The construction and upgrading of latrines were tailored to the specific needs and constraints of the urban slum environment. The design of the latrines considered factors such as space limitations, soil conditions, and cultural preferences. This ensured that the sanitation solutions were feasible, acceptable, and sustainable within the community. The use of tippy-taps as handwashing stations provided a simple, affordable, and culturally appropriate solution for promoting handwashing. Tippy-taps are easy to construct using readily available materials, making them a sustainable option for resource-limited settings. By considering the specific context of the urban slum environment, the intervention ensured that the solutions were not only effective but also feasible, affordable, and acceptable to the community. This context-specific design

contributed to the successful implementation and uptake of the intervention, ultimately leading to a significant reduction in rotavirus infection rates.[11-14]

The findings of this study have profound implications for public health policy and practice, particularly in resource-limited settings grappling with a high burden of diarrheal diseases. The compelling evidence demonstrating the effectiveness of comprehensive WASH interventions in reducing rotavirus infection rates calls for a paradigm shift in public health approaches, prioritizing and scaling up these interventions as a cornerstone of diarrheal disease control strategies. Diarrheal disease control programs often focus on single interventions, such as rotavirus vaccination or oral rehydration therapy. While these interventions are undoubtedly valuable, integrating WASH interventions into these programs can create a synergistic effect, maximizing their impact and contributing to a more holistic and sustainable approach to diarrheal disease prevention. WASH interventions complement other diarrheal disease control measures by addressing the root causes of transmission. While vaccines provide individual protection, WASH interventions address the environmental factors that contribute to the spread of pathogens. By combining these strategies, we can create a multi-layered defense against diarrheal diseases. Integrating WASH interventions into existing programs can enhance their impact by leveraging existing infrastructure and resources. For example, community health workers involved in vaccination campaigns can also promote handwashing and safe water practices, maximizing their reach and efficiency. Integrating WASH into routine health services can contribute to the sustainability of these interventions by ensuring their long-term implementation and monitoring. By embedding WASH practices within the healthcare system, we can create a culture of prevention and promote long-term behavior change. Adequate WASH infrastructure is a fundamental prerequisite for preventing diarrheal diseases and promoting public health. Governments and public health agencies must prioritize investments in WASH infrastructure in urban slums and other high-risk settings, ensuring access to basic amenities that are often taken for granted in more developed areas. Improving access to safe water sources is paramount. This may involve investing in piped water systems, protected wells, or community water treatment facilities. In urban slums, where space is limited and infrastructure is often inadequate, innovative solutions such as rainwater harvesting systems or point-of-use water treatment methods may be necessary. Constructing and maintaining adequate sanitation facilities, such as latrines or toilets, is crucial for preventing open defecation and containing human waste. In densely populated urban slums, this may require innovative sanitation solutions, such as community toilet blocks or shared sanitation facilities, that are designed to meet the specific needs and constraints of the environment. Promoting handwashing requires more than just education, it requires accessible and convenient handwashing facilities. This may involve providing handwashing stations with soap and water in households, schools, and public areas. In urban slums, where space is limited, simple and affordable solutions such as tippy-taps can be effective in promoting handwashing. Investing in WASH infrastructure is not merely an expenditure, it is an investment in human capital. Improved WASH infrastructure leads to healthier communities, reduced healthcare costs, increased productivity, and improved quality of life. Community engagement is not just an optional component of WASH interventions, it is an essential ingredient for their success and sustainability. Involving community members in the design, implementation, and monitoring of WASH programs ensures that the interventions are culturally appropriate, responsive to the community's needs, and ultimately owned by the community itself. Adopting participatory approaches in WASH interventions empowers communities to take ownership of their health and well-being. This can involve conducting community needs assessments, engaging community leaders in decision-making processes, and incorporating local knowledge and practices into intervention design. Building the capacity of community members to manage and maintain WASH infrastructure is crucial for long-term sustainability. This may involve providing training on

latrine construction and maintenance, water filter operation and repair, and hygiene promotion techniques. Encouraging community-led initiatives, such as community hygiene clubs or water and sanitation committees, can foster a sense of collective responsibility for maintaining improved WASH practices. These initiatives can empower communities to take the lead in promoting hygiene behaviors and ensuring the long-term sustainability of WASH interventions. By fostering community participation and ownership, we can transform WASH interventions from external projects into community-driven initiatives, ensuring their long-term success and contributing to sustainable improvements in public health. Health education plays a pivotal role in promoting behavior change and empowering individuals to adopt healthy WASH practices. Public health campaigns should go beyond simply providing information, they should aim to create a deeper understanding of the importance of WASH, the modes of rotavirus transmission, and the benefits of preventive measures. Health education messages should be tailored to the specific needs and cultural context of the target audience. This may involve using different communication channels, such as community meetings, radio broadcasts, or drama performances, to reach different segments of the population. Interactive approaches to health education, such as group discussions, demonstrations, and role-playing, can be more effective than traditional didactic methods. These approaches encourage active participation and allow individuals to practice new skills in a supportive environment. Health education campaigns should address common misconceptions and cultural beliefs that may hinder the adoption of healthy WASH practices. This may involve engaging community leaders and influencers to promote positive behavior change. By empowering individuals with knowledge and skills, health education can contribute to long-term behavior change and sustainable improvements in WASH practices. Robust monitoring and evaluation systems are essential for tracking the progress and impact of WASH interventions, ensuring accountability, and informing program adjustments. Regular monitoring of key indicators provides valuable data for assessing the effectiveness of interventions and identifying areas for improvement. Monitoring should focus on key indicators, such as access to safe water and sanitation facilities, handwashing practices, and rotavirus infection rates. This data can be collected through household surveys, environmental monitoring, and health facility records. Collected data should be analyzed and interpreted to assess the effectiveness of the intervention and identify any challenges or unexpected outcomes. This information can inform program adjustments and ensure that the intervention is achieving its intended goals. Establishing feedback mechanisms, such as community meetings or stakeholder consultations, allows for ongoing communication and collaboration between program implementers, community members, and other stakeholders. This feedback can inform program improvements and ensure that the intervention remains responsive to the community's needs. Monitoring and evaluation are not just bureaucratic exercises, they are essential tools for ensuring the accountability and effectiveness of WASH interventions. By tracking progress, identifying challenges, and adapting strategies, we can maximize the impact of these interventions and contribute to sustainable improvements in public health.[15-18]

The findings of this study resonate with a growing body of research that underscores the effectiveness of WASH interventions in reducing the incidence of rotavirus infection and other diarrheal diseases. Numerous studies conducted across various settings and populations have consistently demonstrated the positive impact of improved WASH practices on child health outcomes. A study in rural Zimbabwe evaluated the impact of a community-led total sanitation and hygiene program (CLTS) on diarrheal disease prevalence. The program focused on empowering communities to eliminate open defecation and adopt improved sanitation practices. The study found a significant reduction in the prevalence of diarrheal diseases, including rotavirus, among children in communities that implemented CLTS. This highlights the potential of community-driven approaches to improve WASH practices and reduce the burden of

rotavirus infection in rural settings. Another study conducted in India assessed the effectiveness of a school-based WASH intervention program in reducing rotavirus infection rates among schoolchildren. The intervention included the provision of safe drinking water, improved sanitation facilities, and hygiene education. The study found a significant decrease in rotavirus infection rates among children in schools that implemented the WASH intervention. This demonstrates the potential of school-based programs to improve WASH practices and protect children from rotavirus infection in educational settings. A study conducted in rural western Kenya investigated the impact of handwashing with soap on rotavirus infection rates among children under five years of age. The study found that children in households that practiced handwashing with soap had a significantly lower risk of rotavirus infection compared to those in households that did not. This emphasizes the critical role of handwashing in preventing rotavirus transmission, even in resource-constrained settings. These studies, along with numerous others, provide converging evidence for the effectiveness of WASH interventions in reducing the incidence of rotavirus infection across different settings and populations. While the findings of this study align with the broader evidence base, it makes a unique contribution by providing evidence for the effectiveness of an integrated WASH intervention in the specific context of urban slums. Urban slums present distinct challenges for WASH interventions that require tailored approaches and innovative solutions. The high population density of urban slums increases the risk of disease transmission due to overcrowding and close proximity to contaminated environments. This necessitates interventions that address both individual and community-level factors, such as household water treatment, improved sanitation facilities, and community-wide hygiene promotion. Urban slums often lack adequate space for constructing and maintaining sanitation facilities. This requires innovative solutions, such as shared sanitation facilities or community toilet blocks, that can accommodate the needs of a large population within a limited space. The lack of adequate water infrastructure may also necessitate alternative water sources, such as rainwater harvesting or community water kiosks. Poverty, unemployment, and limited access to resources can hinder the adoption and maintenance of improved WASH practices in urban slums. This requires interventions that are not only effective but also affordable and accessible to the community. Community engagement and participatory approaches are crucial for ensuring that interventions are tailored to the specific needs and constraints of the community. This study demonstrates that even in these challenging environments, comprehensive WASH interventions can significantly reduce the risk of rotavirus infection. By addressing the unique challenges of urban slums through a multi-faceted approach, the intervention achieved a substantial reduction in rotavirus prevalence, highlighting the potential of WASH interventions to improve child health outcomes even in the most vulnerable settings.[19,20]

4. Conclusion

This study provides compelling evidence that a comprehensive WASH intervention program can significantly reduce rotavirus infection rates among children residing in urban slums. By implementing a multi-faceted approach encompassing household water treatment, improved sanitation facilities, handwashing promotion, and health education, we observed a substantial reduction in the prevalence of rotavirus infection in the intervention group compared to the control group. This finding underscores the critical role of WASH interventions in mitigating the burden of rotavirus disease, a leading cause of morbidity and mortality among children in resource-limited settings. The success of the intervention can be attributed to its comprehensive nature, addressing multiple pathways of rotavirus transmission, and its strong emphasis on community engagement, fostering ownership and sustainability.

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