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Use of Population-based Surveillance to Determine the Incidence of Rotavirus Gastroenteritis in an Urban Slum and a Rural Setting in Kenya

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Abstract

Background—Rotavirus gastroenteritis is a major cause of mortality among children <2 years of age. Disease burden data are important for introducing and sustaining new rotavirus vaccines in immunization programs.

Methods—We analyzed population-based infectious disease surveillance data from 2007 to 2010 from Kenyan sites in rural and urban slum areas. Stool specimens were collected from patients of all ages presenting to study clinics with diarrheal disease and tested for rotavirus by enzyme immunoassay. Incidence rates were adjusted using data on healthcare utilization (from biweekly home visits) and proportion of stools collected at study clinics from patients meeting case definitions.

Results—Rotavirus was detected in 285 (9.0%) of 3174 stools tested, including 122 (11.9%) from children <5 years of age and 162 (7.6%) from participants ≥5 years of age. Adjusted incidence rates for infants were 13,419 and 12,135 per 100,000 person-years of observation in rural and urban areas, respectively. Adjusted incidence rates were high in adults across age ranges. The rates suggest that annually, among children <5 years of age, there are >54,500 cases of rotavirus-associated gastroenteritis in rural Nyanza Province and >16,750 cases in Nairobi urban slums.

Conclusions—Community-based surveillance in urban and rural Kenya suggests that rotavirus plays an important role as a cause of acute gastroenteritis in adults, as well as in children. In

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addition to substantially preventing illness and complications from diarrheal disease in children, rotavirus infant immunization has the potential of indirectly preventing diarrheal disease in older children and adults, assuming children are the predominant sources of transmission.

Keywords

rotavirus; gastroenteritis; diarrhea; population-based incidence; rates; children; adults; Kenya; urban; rural; vaccine; impact

Interest in precise data on burden of rotavirus gastroenteritis has grown due to the recent availability of safe and efficacious new generation rotavirus vaccines.^{1,2} In addition to direct protection, data from high and middle income countries that have introduced rotavirus vaccines suggest that immunization of infants may provide indirect protection by reducing transmission of rotavirus to older children and adults.^{3,4} While data are available on rotavirus disease burden in children <5 years of age from multiple settings,⁵ most of these data are hospital-based, which does not provide a representative and accurate disease incidence data burden in areas where health care utilization is low. In addition, there is limited information on incidence rates for rotavirus-associated diarrhea in older children and in adults, particularly in developing countries.^{6,7}

The Kenya Medical Research Institute (KEMRI) and the US Centers for Disease Control and Prevention (CDC) collaborate on population-based surveillance for infectious disease syndromes and their etiologies in a rural setting and in an urban slum in Kenya; adults in both areas have high (15–20%) HIV seroprevalence.⁸ The surveillance platform has provided opportunities to assess the burden of a variety of syndromes. We assessed incidence and characterized the epidemiology of rotavirus-associated gastroenteritis by age group in these 2 locations. These data may serve as a baseline to monitor impact of introduction (anticipated in 2014) of rotavirus vaccines, including in older children and adults.

METHODS

Study Sites

KEMRI and CDC have collaborated on population-based infectious disease surveillance (PBIDS) since late 2005 in 2 sites in Kenya: Lwak (within Rarieda District in Siaya County), a rural location in Nyanza province in Western Kenya (Fig. 1), and an urban setting in Kibera, a slum in Nairobi.⁹

Surveillance Procedures

The Kenya PBIDS system for diarrheal disease, febrile illness, pneumonia and jaundice surveillance has been described elsewhere [9]. Briefly, trained community interviewers visited participants every 2 weeks, collecting data on illnesses and deaths during the 2 weeks before visit; after September 1, 2009, household visits were increased in frequency to every week to allow for more intensive data collection during the pandemic of influenza A H1N1.¹⁰ Surveillance participants have free access to a well-staffed and supplied field clinic centrally located within 5 km and 1 km of all residences in Lwak and Kibera, respectively.

PBIDS is carried out within 2 of 12 villages in Kibera: Gatwikera and Soweto West. The average population of the surveillance area is 28,500 in a 0.37 km² area (population density = 77,000 persons/km²). Kibera lacks adequate sanitation facilities; human and animal wastes drain into open sewage runoff. The Lwak surveillance area is 100 km² with average population of 25,000 (325 people/km²), and the area is holoendemic for malaria. The 2 areas are 340 km (6–8 travel hours) apart by road. Kibera is at approximately 1600 m altitude and the elevation of Lwak is 1000 m. Surveillance participants included all people living in consenting households within the surveillance areas for a minimum of 4 months (8 consecutive biweekly home visits) between January 1, 2007, and December 31, 2010 (the study period).

For acute diarrheal disease surveillance, we collected stool specimens from consenting patients presenting to the study clinics during the study period. We sampled patients presenting with diarrhea, defined as ≥ 3 loose stools within a 24-hour period. To minimize burden on the laboratory, we sampled no more than 5 children and 5 adults a day (from each site) who had diarrhea without any sign of dehydration or dysentery. However, there were no restrictions on the number of patients sampled who presented with diarrhea and had signs of dehydration (defined as having ≥ 1 of the following signs and symptoms: drinking eagerly or unable to drink or breast-feed, vomits everything, slow skin pinch return ≥ 2 seconds, irritability, sunken eyes, lethargy or unconsciousness) or had evidence of dysentery (defined as reported or visible blood in at least 1 stool during the 24 hours before clinic visit).

A case of rotavirus gastroenteritis was defined as a patient with a diarrheal illness who had rotavirus detected in a stool specimen. To assess the proportion of pathogens detected from patients with diarrhea which was likely associated with illness, we also collected stool specimens from “control” residents of the surveillance area presenting to the clinic without fever, respiratory symptoms or diarrhea during the past 2 weeks, as previously described.^{11,12} Each month, we attempted to enroll a target number of controls for a variety of age groups based on a frequency distribution of ages of patients who presented to the clinics with respiratory or diarrheal disease and for adults, HIV status. We compared proportions of cases and noncases by age group who had rotavirus detected in stool. Odds ratios (OR) and 95% confidence intervals (CIs) were calculated using unconditional logistic regression, adjusting for age group. We used the OR to calculate pathogen-attributable fractions (PAF), which estimate the proportion of cases positive for rotavirus in which it is the likely cause of illness.^{11–13} PAF were calculated as (OR-1)/OR.

Diagnostics

We provided consenting participants meeting the stool collection criteria with a labeled stool container and instructions on how to sample their stool. Stool specimens were collected from patients’ homes within 4 hours of clinic visit, if they were unable to produce stool at the clinic. A sample of whole stool underwent routine enteric microbiology testing¹⁴; in addition, portions were aliquoted into 2 vials, 1 for rotavirus testing and the other was archived. In Kibera, stool specimens were kept at –20°C at the field laboratory and were transported daily to the KEMRI/CDC Nairobi laboratory, where they were stored at –80°C until testing. Specimens were batch shipped to the KEMRI/CDC Enterics laboratory in

Kisumu, Kenya in a dry shipper (at -80°C) for rotavirus testing. Specimens collected in Lwak were transferred to the KEMRI/CDC Kisumu laboratory on a daily basis with cool packs and stored at -80°C until testing.

At the KEMRI/CDC Enterics laboratory in Kisumu, specimen identification numbers were entered into a log book and into a computerized database, and specimens were stored at $2-8^{\circ}\text{C}$. Specimens were batch tested weekly using a commercially available enzyme immunoassay kit (Rotaclone, Meridian Premier, Charlotte, NC) for detection of rotavirus antigen in the human fecal specimens, as previously described.¹⁵

Analysis

Data were analyzed using SAS, version 9.1 (Cary, NC). We calculated crude incidence rates as the number of rotavirus gastroenteritis cases among PBIDS participants per 100,000 participant person-years of observation (PYO). PYO were calculated by totaling person-days for all people who met the residence requirement during each biweekly round and dividing the total number of person-days by 365.25. A participant who moved away from the surveillance area for 4 consecutive months was not counted in the denominator (for calculation of PYO) during or after those 4 months. If that person moved back into the surveillance area, he/she would not be counted in denominator (or numerator) until documented to be living in the surveillance area for 4 months and reconsented to participate in the study.

We used 2 incidence rate adjustments to account for the possibility of cases missed due to gaps in case detection and diagnosis, as previously described.¹⁶ The first (adjustment 1) was based on patients who visited the clinic and did not have a stool specimen collection done despite meeting the criteria for stool collection. The usual reason given for not having a stool specimen obtained was that the patient was not able or willing to produce a stool specimen at the clinic or during the required time after clinic visit (see above). For this extrapolation, we divided the number of participants meeting stool-sampling criteria who had a stool specimen obtained by the total number of all surveillance participants presenting to the clinic meeting stool specimen collection criteria. The resulting proportion was divided into the crude incidence rate to account for those meeting stool specimen collection criteria who were not cultured.

A second adjustment (adjustment 2) was based on dividing the number of patients who had a diarrheal illness (based on data from the home visits) and who visited the study clinic by the total number of patients who had diarrheal illness and visited any clinic (including nonstudy clinics where information and specimens are not collected for this surveillance)—thus, the denominator would include patients who felt they were sick enough to visit a clinic but did not have the opportunity for stool specimen collection. This figure was divided into adjustment 1 to yield adjustment 2. This adjusted rate was then multiplied by the PAF (see above) to achieve the final adjusted rate.

Because of the likelihood that healthcare-seeking and stool-sampling patterns vary by type of diarrheal syndrome, adjustments 1 and 2 and PAF correction were initially done separately for diarrhea without dehydration, diarrhea with evidence of dehydration and

dysentery (blood in stool). The adjusted rates for each diarrheal syndrome by age group were then summed to provide the final adjusted rates for rotavirus diarrhea by age group for Kibera and Lwak. CIs for the crude incidence rates were calculated using the Exact method.¹⁷ CIs for the final adjusted incidence rates were calculated using the same adjustments; that is, the lower and upper ends of the exact CIs were divided by adjustment 1 and then by adjustment 2, and then those figures were multiplied by the PAF.

We used incidence rates from this study to estimate the annual number of cases of rotavirus gastroenteritis occurring among people within the same age groups based on 2009 census data in rural Nyanza Province and in urban Nairobi.¹⁸ This project was approved by the Ethical Review Committee of KEMRI (Protocol #932 and #1899) and Institutional Review Board of CDC (Protocol #4566).

RESULTS

We enrolled 48,337 and 35,063 persons in Kibera and Lwak in the study between 2007 and 2010, who contributed 110,592 and 102,217 PYO, respectively. The overall crude incidence rate of rotavirus gastroenteritis was 153/100,000 PYO (Kibera) and 113/100,000 PYO (Lwak). In Lwak, crude incidence was highest among children <12 months of age (671/100,000 PYO); in Kibera, toddlers, 12–23 months of age, had the highest rate (504/100,000 PYO; Table 1 and Table 2). In Kibera, rotavirus was detected in 170 (7.8%) of 2166 stools from patients with diarrhea compared with 6 (2.1%) of 289 control-patients (PAF = 0.75). In Lwak, rotavirus was detected in 115 (11.4%) of 1008 stools collected from patients with diarrhea, compared with 9 (1%) of 737 control-patients (PAF = 0.9). Thus, rural Lwak residents had an increased likelihood that an episode of acute gastroenteritis was associated with detection of rotavirus in stool when compared with urban Kibera residents (relative risk = 1.46; 95% CI = 1.16–1.83) and given differences in PAF, a greater likelihood that rotavirus was the cause of the episode of gastroenteritis. The difference in rate of detection of rotavirus in stools from control residents of Kibera when compared with control residents in Lwak was not statistically significant. Mild diarrhea accounted for many incidences in both sites; however, in Lwak, a greater proportion of rotavirus gastroenteritis was associated with dehydration than in Kibera for all age groups, especially so for children <24 months of age (Table 3 and Table 4).

The overall adjusted incidence rates were 1157/100,000 PYO and 1427/100,000 PYO in Kibera and Lwak, respectively, with highest rates in children 12–23 months of age followed by infants (<12 months of age; Table 3 and Table 4). Rotavirus gastroenteritis incidence rates were >220/100,000 PYO for each age group 5 years of age with the highest rate (437/100,000 PYO) in Kibera in persons 35–49 years of age, which was about one-sixth of the rate calculated for children 24–59 months of age (Table 3). In Lwak, the highest rates in adults were in the 18–34 year age group (982/100,000 PYO), which was more than half of the rate calculated for 24–59 month olds (Table 4).

HIV test results were available from a limited number of patients. In Kibera, among 39 rotavirus cases 18 years old tested for HIV antibodies, 9 (23.1%) were HIV-infected, compared with 133 (23.9%) of 557 nonrotavirus-associated diarrhea cases tested for HIV

infection. In Lwak, among 29 rotavirus cases 18 years old, tested for HIV antibodies, 10 (34.5%) were HIV-infected compared with 154 (50.2%) of 307 nonrotavirus-associated diarrhea cases tested for HIV infection (relative risk = 0.55; 95% CI = 0.26–1.15).

Annual crude rotavirus rates varied across the 4 years of observation from 45 to 195/100,000 PYO in Kibera and from 85 to 160/100,000 PYO in Lwak. Throughout the 4-year period, rotavirus gastroenteritis occurred year round without consistent, specific high incidence peaks, although in Kibera, peaks occurred during the cool, dry months of July and August for 3 of the 4 years (Fig. 2).

DISCUSSION

This study provides community population-based incidence data for rotavirus gastroenteritis in children and adults as a result of rigorously defined denominators and active surveillance to identify cases and to adjust incidence based on the proportion of cases likely missed. The incidence rates can be used to estimate absolute numbers of cases for people living in similar settings, using population census data. While demonstration of high rates in children is not unexpected, the study also showed that rotavirus is an important cause of gastroenteritis in adults in these settings in Kenya.

Rotavirus crude incidence rates varied substantially annually over the 4-year course of this study. This confirms earlier reports of annual incidence variation¹⁹ and highlights the importance of multiple years of surveillance (and use of alternative approaches, like case-control studies, cluster designed interventions and severity-impact investigations) to assess and document impact of rotavirus vaccine postintroduction. For example, if rotavirus vaccine had been introduced in 2007, it would have been tempting to ascribe the 53% reduction in incidence (based on surveillance data from a national surveillance system) in Lwak when comparing 2008 data with 2007 data, as evidence of vaccine impact; conversely, in Kibera, the crude rate increased 4-fold from 2008 to 2009; if vaccine introduction had occurred in 2008, there might have been premature and incorrect conclusions of ineffectiveness (or increased associated risk) of the immunization program, potentially negatively impacting continued enthusiasm.

Rotavirus is often described as an “egalitarian” virus, infecting people regardless of their location or socioeconomic status,²⁰ although severity and fatal outcome are dictated by comorbidities and access to health care (including oral rehydration solutions).^{5,19} Despite vastly different ecologies found in the sparsely populated rural western Kenya and densely populated urban Nairobi, interestingly, the overall rates of rotavirus disease in the 2 areas are quite similar. The higher incidence we observed of dehydration-associated rotavirus gastroenteritis in the rural area might reflect differential access to rehydration in the 2 areas.

A value of population-based incidence rates is that one can estimate numbers of people affected by a disease and project the number of illness episodes that can be prevented by applying interventions of known effectiveness. For instance, the 2009 census showed that there were 5.4 million people living in Nyanza Province (where the rural Lwak surveillance site is located), including 810,000 children <5 years of age. Given an adjusted annual

incidence rate of rotavirus gastroenteritis in Lwak of 6779 cases per 100,000 children <5 years of age, we estimate that there are >54,500 cases per year in children in the Province (which represents 13.5% of the national population). If we assume the efficacy of rotavirus immunization in this setting to be approximately 60%² and an 80% vaccine coverage rate, then about 26,000 cases would be preventable per year in Nyanza Province alone. Likewise, there is an estimated 1.9 million people living in urban slums in Nairobi with an estimated 285,000 children <5 years of age. The adjusted incidence rate in Kibera for children <5 years of age of 5887 cases per 100,000 population per year, translates to >16,750 cases per year. Using the same vaccine efficacy and estimated coverage rates as above, >8000 cases of rotavirus gastroenteritis could be prevented per year in <5 years of age in Nairobi urban slums.

Based on data from a variety of studies and sites, it would be possible to estimate preventable burden from the estimated proportion of rotavirus gastroenteritis that requires hospitalization and the proportion of rotavirus gastroenteritis associated with mortality. Our study was not designed to assess mortality from rotavirus or to calculate economic impact contributing to disease burden calculations. Given that rotavirus-associated mortality is associated with poor or delayed access to rehydration options and that provision of good quality health care is a component of participation in the PBIDS from which the incidence rates are calculated, we did not expect to observe many deaths. However, most children in Kenya do not have this level of access to health care, so the rates of rotavirus illness determined during this study could be used to estimate mortality, as has been done during global estimates of rotavirus-associated burden.^{5,19,20} Having estimates of overall burden provide a tangible way for policy-makers to assess likely impact of interventions, and for donors and vaccine developers to consider potential impact of more effective vaccine regimens.

HIV has been known to increase the incidence, shedding and severity of infections due to a variety of pathogens²¹⁻²³ and studies have suggested that HIV-infected adults have an increased risk for rotavirus gastroenteritis.^{24,25} While surprisingly high rates of rotavirus-associated diarrhea were shown in our study, rotavirus-infected adults were not more likely to be infected with HIV than adults with diarrhea due to other causes; thus, it did not appear that HIV infection was a specific risk factor for rotavirus infection. Nonetheless, the HIV-infection rates for adults with diarrhea (with or without rotavirus as an etiology) were higher than the seroprevalences of HIV infection in both areas, consistent with evidence that HIV infection is associated with greater risk of illness from a variety of gastrointestinal pathogens.

More data are needed to assess the impact (including severity and outcome) of rotavirus gastroenteritis in adults, especially in areas with high HIV seroprevalence. Vaccinating children will be key in directly reducing childhood associated morbidity and death, and there may be an indirect benefit of reducing infections in older children and adults.²⁵

While this study was unique in terms of its community-based methods identifying rotavirus gastroenteritis in the urban and rural communities we surveyed, and for providing reliable basis for rate adjustments, limitations may have led to underestimates or overestimates of

the burden of disease. Because of transport requirements to the Kisumu laboratory, stool specimens were often processed >24 hours after collection. In calculating adjusted incidence rates, we assumed that persons with diarrhea who reported visiting any clinic had similar rotavirus gastroenteritis incidence rates as those seen in the study field clinic. We also assumed that severity of illness for patients with diarrhea (and the 3 categories of dehydration, dysentery and mild diarrhea) who provided stool for testing were not different from those of patients who were not sampled. These assumptions would be erroneous if there was a systematic bias with regard to whether persons with moderate to severe diarrhea went to the designated field clinic and whether patients and clinicians were more aggressive about sampling, based on the type or severity of diarrhea. It also should be noted that freezing and batch testing of specimens may have reduced sensitivity of the assay.

The findings of this study provide evidence for high community-based incidence of rotavirus gastroenteritis, as well as an important role of rotavirus as a cause of diarrheal disease in adults, providing the basis for evaluating indirect protection in older children and adults when rotavirus immunization programs are implemented. High incidence rates are shown in both rural and urban slum settings, supporting expectations for substantial impact of universal rotavirus immunization of infants and toddlers in Kenya, and likely elsewhere in Africa. In addition, year to year variation of rotavirus-associated diarrhea incidence highlights that evaluation of impact of rotavirus immunization will require multiple years of observation.

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FIGURE 1. Map of Kenya with insets showing location of study sites.

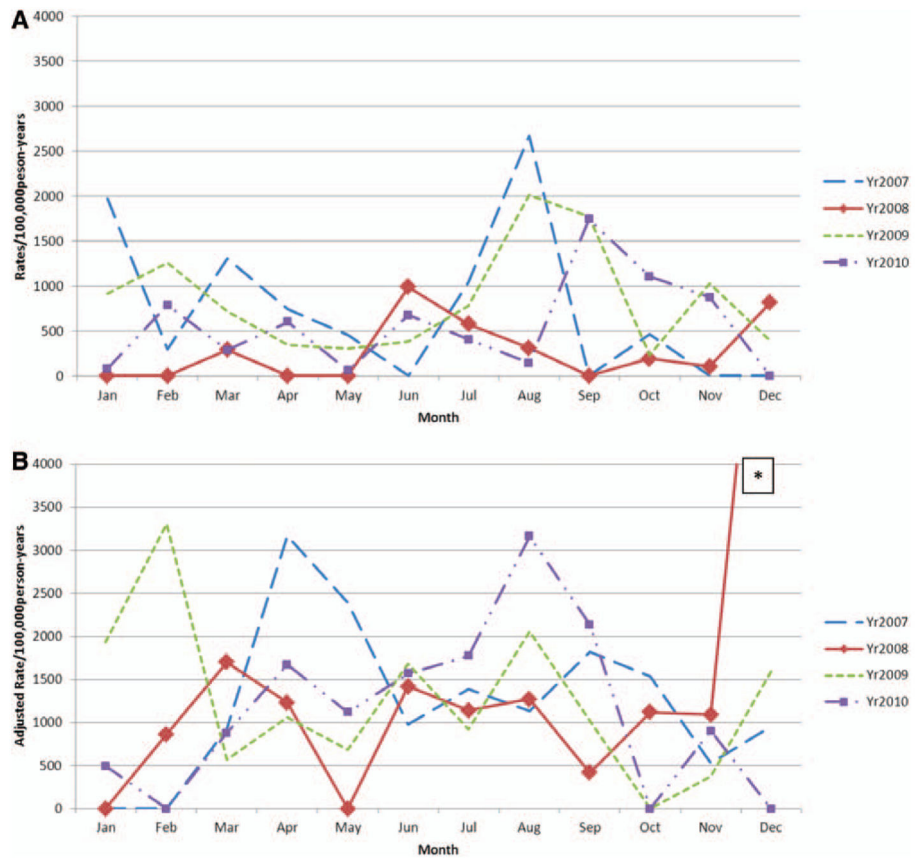


FIGURE 2. Adjusted annual incidence of rotavirus gastroenteritis by month: A) Kibera (2007–2010) and B) Lwak (2007–2010). *Actual value of this off-scale data point (December 2008) is 8000/100,000 person years of observation.

TABLE 1
 Detection of Rotavirus in Stool From Cases and Controls by Age Group, Kibera (Urban Slum Site)

	Cases			Controls			PAF
	Number of Stool Specimens Processed	Rotavirus Detected n (%)	Number of Stool Specimens Processed	Rotavirus Detected n (%)	PAF		
Age							
<12 months	166	22 (13.3)	25	1 (4)	0.73		
12-23 months	184	28 (15.2)	8	0 (0)	1.00*		
24-59 months	412	23 (5.6)	20	0 (0)	1.00*		
<5 years	762	73 (9.6)	53	1 (1.9)	0.82		
5-9 years	229	12 (5.2)	30	1 (3.3)	0.38		
10-17 years	260	18 (6.9)	53	1 (1.9)	0.74		
18-34 years	585	43 (7.4)	101	1 (0.9)	0.87		
35-49 years	259	21 (8.1)	46	2 (4.3)	0.48		
50+ years	58	2 (3.4)	6	0 (0)	1.00*		
5 years	1391	96 (6.9)	236	5 (2.1)	0.72		
Total	2166	170 (7.8) [‡]	289	6 (2.1)	0.75		
Sex							
Male	1053	77 (7.3)	139	3 (2.2)	0.71		
Female	1113	92 (8.3)	151	2 (1.3)	0.85		
Year							
2007	200	20 (10.0)	0	0 (0.0)	1.00*		
2008	435	18 (4.1)	29	3 (10.3)	1.69		
2009	730	62 (8.5)	162	1 (0.6)	0.94		
2010	801	70 (8.7)	99	2 (2.0)	0.79		

* PAF not calculable, thus otherwise specified as 1.

[‡] Age information was not available for 13 patients, including 1 patient with rotavirus detected in stool.

TABLE 2
 Detection of Rotavirus in Stool From Cases and Controls by Age Group, Lwak (Rural Site)

	Cases			Controls			PAF
	Number of Stool specimens Processed	Rotavirus Detected n (%)	Number of Stool Specimens Processed	Rotavirus Detected n (%)	Number of Stool Specimens Processed	Rotavirus Detected n (%)	
Age							
<12 months	107	23 (21.5)	48	1 (2.1)			0.92
12-23 months	85	20 (23.5)	52	1 (1.9)			0.94
24-59 months	75	6 (8)	87	1 (1.1)			0.87
<5 years	267	49 (18.4)	187	3 (1.6)			0.93
5-9 years	53	3 (5.7)	118	1 (0.8)			0.86
10-17 years	122	11 (9)	117	0 (0)			1.00*
18-34 years	252	31 (12.3)	152	3 (2)			0.86
35-49 years	165	11 (6.7)	98	1 (1)			0.86
50+ years	149	10 (6.7)	65	1 (1.5)			0.78
5 years	741	66 (8.9)	550	6 (1.1)			0.89
Total	1008	115 (11.4)	737	9 (1.2)			0.90
Sex							
Male	454	48 (10.6)	262	3 (1.1)			0.90
Female	554	67 (12.1)	475	6 (1.3)			0.91
Year							
2007	276	39 (14.1)	0	0 (-)			1.00*
2008	251	22 (8.8)	69	2 (2.9)			0.69
2009	267	29 (10.9)	311	4 (1.3)			0.89
2010	214	25 (11.7)	357	3 (0.8)			0.94

* PAF not calculable, thus otherwise specified as 1.

TABLE 3

Crude and Adjusted Incidence Rates for Rotavirus Gastroenteritis (GE), Kibera (January 1, 2007, to December 31, 2010)

Age	Syndrome	Rotavirus GE Cases	PYO	Crude IR	95% CI		% GE Sampled at Clinic	Adjusted		% GE Cases Visiting Field Clinic	Adjusted		Final Adjusted		95% CI		
					Lower	Upper		Adjustment 1 Cases	Rate 1		Adjustment 2 Cases	Rate 2	Adjustment 3 Cases	Rate 3	Lower	Upper	
<12 months	Overall	14	3047	459.5	272.1	775.8		321	10,549.4		451	14,799.2	0.82	370	12,135	10,959	13,438
	Dehydration	4	3047	131.3	49.3	349.8	10.3	39	1274.5	69.5	56	1833.9	0.82	46	1504	1126	2009
	Dysentery	2	3047	65.6	16.4	262.5	23.2	9	283.3	100	9	283.3	0.82	7	232	111	485
12-23 months	Mild Diarrhea	8	3047	262.6	131.3	525.0	2.9	274	8991.6	70.9	386	12,682.0	0.82	317	10,399	9315	11,610
	Overall	21	4167	504.0	328.6	772.9		479	11,483.1		652	15,642.4	0.82	534	12,827	11,784	13,962
	Dehydration	4	4167	96.0	36.0	255.8	9.1	44	1060.7	73.9	60	1435.3	0.82	49	1177	890	1557
24-59 months	Dysentery	3	4167	72.0	23.2	223.2	29.8	10	241.4	100	10	241.4	0.82	8	198	100	392
	Mild Diarrhea	14	4167	336.0	199.0	567.3	3.3	424	10,181.0	72.9	582	13,965.7	0.82	477	11,452	10,469	12,527
	Overall	21	12,553	167.3	109.1	256.6		332	2641.6		388	3093.6	0.82	318	2537	2273	2831
<5 years	Dehydration	1	12,553	8.0	1.1	56.6	10.4	10	76.7	79.2	12	96.8	0.82	10	79	43	148
	Dysentery	3	12,553	23.9	7.7	74.1	33.7	9	70.9	88.9	10	79.8	0.82	8	65	33	130
	Mild Diarrhea	17	12,553	135.4	84.2	217.8	5.4	313	2494.0	85.5	366	2917.0	0.82	300	2392	2136	2678
5-9 years	Overall	56	19,767	283.3	218.0	368.1		1092	5522.9		1419	7179.4	0.82	1164	5887	5558	6235
	Dehydration	9	19,767	45.5	23.7	87.5	9.9	91	459.9	74.4	122	618.1	0.82	100	507	417	617
	Dysentery	8	19,767	40.5	20.2	80.9	31	26	130.6	94.1	27	138.7	0.82	22	114	75	172
10-17 years	Mild Diarrhea	39	19,767	197.3	144.2	270.0	4	975	4932.5	76.8	1270	6422.5	0.82	1041	5266	4956	5596
	Overall	11	16,764	65.6	36.3	118.5		78	464.1		94	560.0	0.72	68	403	318	512
	Dehydration	1	16,764	6.0	0.8	42.3	37.5	3	15.9	80.2	3	19.8	0.72	2	14	4	51
18-34 years	Dysentery	3	16,764	17.9	5.8	55.5	43.8	7	40.9	80	9	51.1	0.72	6	37	17	81
	Mild Diarrhea	7	16,764	41.8	19.9	87.6	10.3	68	407.4	83.3	82	489.0	0.72	59	352	273	454
	Overall	14	17,203	81.4	48.2	137.4		77	446.0		93	539.8	0.72	67	389	306	494
Dehydration	Dehydration	0	17,203	0.0	-	-	28.6	0	0.0	81.5	0	0.0	0.72	0	0	-	-
	Dysentery	3	17,203	17.4	5.6	54.1	53.4	6	32.7	100	6	32.7	0.72	4	24	9	62
	Mild Diarrhea	11	17,203	63.9	35.4	115.5	15.5	71	413.3	81.5	87	507.2	0.72	63	365	285	468
Dehydration	Overall	35	40,046	87.4	62.8	121.7		154	385.6		200	500.4	0.72	144	360	306	424
	Dehydration	3	40,046	7.5	2.4	23.2	19.2	16	39.0	66.8	23	58.3	0.72	17	42	26	68

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Syndrome	Rotavirus GE Cases	PYO	Crude IR	95% CI		% GE Sampled at Clinic	Adjusted		% GE Cases Visiting Field Clinic	Adjusted		Final Adjusted		95% CI		
				Lower	Upper		Adjustment 1 Cases	Rate 1		Adjustment 2 Cases	Rate 2	Adjustment 3 Cases	Rate 3	Lower	Upper	
Dysentery	11	40,046	27.5	15.2	49.6	59.3	19	46.3	66.7	28	69.4	0.72	20	50	32	78
Mild Diarrhea	21	40,046	52.4	34.2	80.4	17.5	120	300.3	80.6	149	372.6	0.72	107	268	222	324
Overall	14	13,600	102.9	61.0	173.8		52	383.3		83	606.6	0.72	59	437	339	563
Dehydration	0	13,600	0.0	-	-	9.1	0	0.0	64.6	0	0.0	0.72	0	0	-	-
Dysentery	6	13,600	44.1	19.8	98.2	59.1	10	74.7	50	20	149.4	0.72	15	108	64	180
Mild Diarrhea	8	13,600	58.8	29.4	117.6	19.1	42	308.6	67.5	62	457.2	0.72	45	329	246	441
Overall	2	3213	62.2	15.6	248.9		8	249.0		10	308.8	0.72	7	222	107	463
Dehydration	0	3213	0.0	-	-	0	0	0.0	100	0	0.0	0.72	0	0	-	-
Dysentery	1	3213	31.1	4.4	221.0	50	2	62.2	82.4	2	75.5	0.72	2	54	12	240
Mild Diarrhea	1	3213	31.1	4.4	221.0	17.2	6	180.7	77.5	7	233.2	0.72	5	168	72	390
Overall	76	90,826	83.7	66.8	104.8		376	413.6		481	530.1	0.72	347	382	344	424
Dehydration	4	90,826	4.4	1.7	11.7	23.0	17	19.2	72.8	24	26.4	0.72	17	19	12	30
Dysentery	24	90,826	26.4	17.7	39.4	55.0	44	48.1	70.6	62	68.1	0.72	45	49	37	66
Mild Diarrhea	48	90,826	52.8	39.8	70.1	15.3	315	346.3	79.5	396	435.6	0.72	285	314	279	352
Overall*	169	110,592	152.8	131.4	177.7		1467	1326.8		1777	1606.6	0.72	1279	1157	1095	1222
Dehydration	13	110,592	11.8	6.8	20.2	11.1	117	106.0	73.9	159	143.4	0.72	114	103	86	124
Dysentery	32	110,592	28.9	20.5	40.9	44.8	71	64.5	82.4	87	78.3	0.72	62	56	44	72
Mild Diarrhea	87	110,592	78.7	63.8	97.1	7.3	1187	1073.2	77.5	1531	1384.8	0.72	1103	997	940	1058
Sex																
Male	57	56,433	101.0	77.9	130.9		570	1010.3		753	1334.5	0.71	535	948	871	1031
Dehydration	4	56,433	7.1	2.7	18.9	10.5	38	67.6	73.7	52	91.8	0.71	37	65	47	90
Dysentery	17	56,433	30.1	18.7	48.5	41.6	41	72.4	76.5	53	94.6	0.71	38	67	49	92
Mild Diarrhea	36	56,433	63.8	46.0	88.4	7.3	491	870.3	75.8	648	1148.1	0.71	460	815	744	893
Overall	75	54,159	138.5	110.4	173.7		803	1482.1		1014	1871.9	0.85	862	1591	1488	1701
Dehydration	9	54,159	16.6	8.6	31.9	11.7	77	141.7	74.2	103	190.9	0.85	88	162	132	200
Dysentery	15	54,159	27.7	16.7	45.9	48.2	31	57.5	88.2	35	65.2	0.85	30	55	39	79
Mild Diarrhea	51	54,159	94.2	71.6	123.9	7.3	695	1282.9	79.4	875	1615.8	0.85	744	1373	1278	1476
Dehydration	8	27,702	28.9	14.4	57.7	14.5	55	198.9	73.5	75	270.6	0.94	70	254	201	321
Dysentery	11	27,702	39.7	22.0	71.7	60.3	18	65.8	88.9	21	74.1	0.94	19	70	45	109
Mild Diarrhea	31	27,702	111.9	78.7	159.1	10.1	308	1113.5	78.4	393	1420.3	0.94	370	1335	1206	1478

TABLE 4

Crude and Adjusted Incidence Rates for Rotavirus Gastroenteritis (GE), Lwak (January 1, 2007, to December 31, 2010)

Age	Syndrome	Rotavirus cases	PYO	Crude IR	95% CI			% GE Sampled at Clinic		Adjusted		% GE Cases Visiting Field Clinic		Adjusted			Final Adjusted		95% CI	
					Lower	Upper	Upper	Rate 1	Rate 1	Cases 1	Rate 1	Cases 2	Rate 2	PAF	Cases 3	Rate 3	Lower	Upper		
<12 months	Overall	23	3426	671	446.1	1010.2	267	7803.6	498	14,549.5	0.93	462	13,494	12,318	14,782					
	Dehydration	16	3426	467	286.1	762.3	101	2955.2	168	4910.7	0.93	156	4,555	3,893	5,328					
	Dysentery	0	3426	0	0.0	0.0	0	0.0	0	0.0	0.93	0	0	0	0					
12-23 months	Mild diarrhea	7	3426	204	97.4	428.6	166	4848.4	330	9638.7	0.93	306	8,940	7,992	9,999					
	Overall	20	3242	617	398.0	956.2	277	8547.2	524	16,158.0	0.93	486	14,986	13,711	16,380					
	Dehydration	14	3242	432	255.8	729.2	89	2745.8	146	4514.8	0.93	136	4,187	3,539	4,954					
24-59 months	Dysentery	0	3242	0	0.0	0.0	0	0.0	0	0.0	0.93	0	0	0	0					
	Mild diarrhea	6	3242	185	83.1	412.0	188	5801.3	377	11,643.2	0.93	350	10,799	9,725	11,991					
	Overall	6	9275	65	29.1	144.0	94	1018.3	177	1907.9	0.93	164	1,770	1,519	2,062					
<5 years	Dehydration	2	9275	22	5.4	86.2	13	141.4	23	251.5	0.93	22	233	153	356					
	Dysentery	0	9275	0	0.0	0.0	0	0.0	0	0.0	0.93	0	0	0	0					
	Mild diarrhea	4	9275	43	16.2	114.9	81	876.9	154	1656.4	0.93	142	1,536	1,304	1,810					
5-9 years	Overall	49	15,943	307	232.3	406.7	621	3893.0	1165	7308.7	0.93	1081	6,779	6,386	7,195					
	Dehydration	32	15,943	201	141.9	283.8	204	1281.2	345	2161.5	0.93	320	2,005	1,797	2,237					
	Dysentery	0	15,943	0	0.0	0.0	0	0.0	0	0.0	0.93	0	0	0	0					
10-17 years	Mild diarrhea	17	15,943	107	66.3	171.5	416	2611.9	821	5147.1	0.93	761	4,774	4,446	5,125					
	Overall	3	19,443	15	5.0	47.8	42	215.1	90	460.4	0.89	79	408	328	509					
	Dehydration	0	19,443	0	0.0	0.0	0	0.0	0	0.0	0.89	0	0	0	0					
18-34 years	Dysentery	0	19,443	0	0.0	0.0	0	0.0	0	0.0	0.89	0	0	0	0					
	Mild diarrhea	3	19,443	15	5.0	47.8	42	215.1	90	460.4	0.89	79	408	328	509					
	Overall	11	18,818	58	32.4	105.6	72	384.5	121	645.4	0.89	108	573	474	692					
18-34 years	Dehydration	0	18,818	0	0.0	0.0	0	0.0	0	0.0	0.89	0	0	0	0					
	Dysentery	6	18,818	32	14.3	71.0	26	138.6	33	173.3	0.89	29	154	107	221					
	Mild diarrhea	5	18,818	27	11.1	63.8	46	245.9	89	472.1	0.89	79	419	336	522					
18-34 years	Overall	32	23,725	135	95.4	190.7	148	624.8	272	1146.8	0.89	241	1,017	897	1,154					
	Dehydration	3	23,725	13	4.1	39.2	14	59.6	23	98.1	0.89	21	87	57	134					

Syndrome	Rotavirus cases	PYO	Crude IR	95% CI		% GE Sampled at Clinic	Adjusted		% GE Cases Visiting Field Clinic	Adjusted			Final Adjusted		95% CI	
				Lower	Upper		Cases 1	Rate 1		Cases 2	Rate 2	PAF	Cases 3	Rate 3	Lower	Upper
Dysentery	9	23,725	38	19.7	72.9	40.5	22	93.6	73.7	30	127.0	0.89	27	113	77	165
Mild diarrhea	20	23,725	84	54.4	130.7	17.9	112	471.7	51.2	219	921.7	0.89	194	818	710	941
Overall	11	10,312	107	59.1	192.6	19.5	42	411.8	52.6	76	736.3	0.89	67	653	515	830
Dehydration	0	10,312	0	0.0	0.0	19.5	0	0.0	57.0	0	0.0	0.89	0	0	0	0
Dysentery	6	10,312	58	26.1	129.5	35.6	17	163.6	61.9	27	264.2	0.89	24	234	157	349
Mild diarrhea	5	10,312	48	20.2	116.5	19.5	26	248.2	52.6	49	472.1	0.89	43	419	311	564
Overall	10	13,977	72	38.5	133.0	18.6	52	374.1	54.1	99	705.8	0.89	88	626	508	772
Dehydration	4	13,977	29	10.7	76.3	18.6	21	153.7	57.1	40	284.3	0.89	35	252	181	351
Dysentery	3	13,977	21	6.9	66.6	24.5	12	87.6	49.5	21	153.4	0.89	19	136	87	213
Mild diarrhea	3	13,977	21	6.9	66.6	16.2	19	132.8	50.5	37	268.0	0.89	33	238	169	334
Overall	67	86,274	78	61.1	98.7	20.3	363	420.6	56.4	679	786.7	0.89	602	698	644	756
Dehydration	7	86,274	8	3.9	17.0	31.6	35	40.0	64.5	61	71.0	0.89	54	63	48	82
Dysentery	24	86,274	28	18.6	41.5	14.3	76	88.1	50.5	118	136.6	0.89	105	121	100	147
Mild diarrhea	36	86,274	42	30.1	57.8	17.2	252	292.5	82.1	500	579.1	0.89	443	514	468	564
Overall	116	102,217	113	94.6	136.1	28.6	864	845.2	50.6	1614	1578.9	0.90	1459	1427	1356	1502
Dehydration	39	102,217	38	27.9	52.2	9.6	227	222.0	57.8	393	384.3	0.90	355	347	313	386
Dysentery	24	102,217	23	15.7	35.0	28.6	84	82.1	65.3	128	125.7	0.90	116	114	95	136
Mild diarrhea	53	102,217	52	39.6	67.9	9.6	553	541.2	50.6	1093	1068.9	0.90	988	966	908	1029
Sex																
Male	48	48,253	99	75.0	132.0	15.6	395	819.5	57.5	764	1583.6	0.90	689	1428	1326	1539
Dehydration	14	48,253	29	17.2	49.0	29.7	90	185.6	64.3	156	322.9	0.90	141	291	247	344
Dysentery	9	48,253	19	9.7	35.8	9.1	30	62.9	49.1	47	97.8	0.90	43	88	65	119
Mild diarrhea	25	48,253	52	35.0	76.7	18.8	276	571.0	58.0	561	1162.9	0.90	506	1049	961	1144
Overall	68	53,964	126	99.4	159.8	27.9	465	862.0	66.1	845	1565.5	0.91	766	1420	1323	1524
Dehydration	25	53,964	46	31.3	68.6	10.1	133	245.9	52.1	229	424.0	0.91	208	385	3356	441
Dysentery	15	53,964	28	16.8	46.1	10.1	54	99.8	52.1	81	151.0	0.91	74	137	109	172
Mild diarrhea	28	53,964	52	35.8	75.1	10.1	279	516.2	52.1	534	990.5	0.91	485	898	822	982

Incidence rates (IR) per 100,000 PYO.

Adjustment 1 based on percentage of patients who met sample collection criteria who provided a stool sample (see Methods).

Adjustment 2 (total adjustment) based on the patients with diarrhea or dysentery during home visit, who visited the field clinic (adjusting the adjustment 1 rates—see methods).

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