

Prevalence of gastrointestinal pathogens in Sub-Saharan Africa: systematic review and meta-analysis

Stephanie M. Fletcher,¹ Damien Stark,^{1,2} John Ellis¹

¹iThree Institute and Department of Medical and Molecular Biosciences, University of Technology, Sydney;

²Division of Microbiology, St. Vincent's Hospital, Sydney, Australia

Abstract

A significant proportion of vulnerable people in sub-Saharan Africa (SSA) remain at risk for contracting diarrhoeal diseases due to the presence of many risk factors facilitating their transmission. A systematic review of published articles from the SSA region was done to determine the prevalence and types of diarrhoeal pathogens in circulation, based on a search of databases, including EBSCO host, PubMed, Scopus, Science Direct, Google scholar and Web of Science was done between September 2009 and December 2010. Data were summarized from 27 studies, with pooled data analysed and reported. Pathogens were isolated from between 26.8-65.6% of cases, with an overall isolation rate of 55.7% (95% CI, 48.2-62.9%). Isolation rates were highest amongst adult cases followed by children, and the odds of isolating a pathogen was greater in diarrhoeal cases (Odds Ratio 4.93 (95% CI, 1.99 to 12.23), than in asymptomatic controls. Overall isolation ranged from 8% to 99%; and heterogeneity testing suggests differences between age groups ($Q=5.806$; $df=2$, $P=0.055$). Mixed *E. coli* spp., (29.95%), *Cryptosporidium* (21.52%), *Cyclospora* (18%), *Entamoeba*. (13.8%), *Shigella* spp. (10.49%), *Salmonella* spp. (8.36%), and *Campylobacter* spp. (8.33%), were most commonly reported, and rotavirus was the most common virus isolated. This is the first review to look at the range of enteric pathogens circulating in SSA, and has confirmed high rates of isolation of pathogens from diarrhoeal cases. Public health practitioners can use this information to understand the challenges related to diarrhoeal illness and set priorities for their prevention and control.

Introduction

The burden of gastrointestinal (GI) illness

in developing countries remains significantly high, despite a marked decrease in mortality rates from 4.6 million in 1980 to about 1.5 million annually in 1999.¹⁻³ It is estimated that approximately 1.87 million (CI: 1.56-2.19) children die from diarrhoea before reaching their fifth birthday.⁴ Diarrhoeal diseases account for 1/5 of all child deaths, 78% of which are concentrated in the African and South East Asian Regions.^{4,5} Several studies have shown that the burden of GI remain particularly high in the African continent, especially in areas characterized by poverty. Three of the Millennium Development Goals (MDG) are associated with the burden of diarrhoeal diseases. The progress towards achieving the targets of MDG 7- to halve the proportion of people without sustainable access to improved sanitation; MDG 1- to eradicate extreme poverty and hunger and MDG 4- to reduce child deaths by two thirds by 2015, has been slow.^{6,7}

Current trends suggest that many countries in SSA will not reach these target as only about 31% of people have access to improved sanitation,⁸ leaving a significant proportion of vulnerable people at risk from infectious diseases.⁷ Infectious organisms can be transmitted through a variety of routes,^{9,10} the epidemiology of GI illness is influenced by the context in which they are transmitted and differs between developing and developed countries.^{2,4,11} Recent studies have described a high incidence of pathogenic organisms, especially in children in the SSA region when compared with the rest of the world.^{2,4,11} Since the African continent is disproportionately affected by a high burden of illness from GI illness, it is important to understand the types and prevalence of pathogens that are responsible in SSA countries and how this can influence planning for prevention and control programmes. The high prevalence and burden of HIV infection in countries in SSA populations have also increased the risk of acute and persistent diarrhoea. There is much value in describing not just a single pathogen, but a range of pathogens, as many are transmitted via similar routes of exposure. The application of prevention and control measures at each route of exposure can impact several pathogens at the same time.¹²⁻¹⁴ The aim of this paper is to describe the common diarrhoeal pathogens, and discuss their public health implications in the Sub-Saharan African context. A systematic review of studies from the SSA region was done, as it provides empirical information through the appraising and synthesizing of evidence from primary studies, while reducing the reviewer's own bias.¹⁵⁻¹⁷

Correspondence: Prof. John Ellis, The iThree Institute and Department of Medical and Molecular Biosciences, University of Technology Sydney, PO Box 123, Broadway, NSW 2007, Australia.
Tel. +61.2.95148382 - Fax: +61.2.95141656.
E-mail: john.ellis@uts.edu.au

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Materials and Methods

Search strategy and selection criteria

A search for studies on diarrhoeal pathogens and associated risk factors conducted in sub-Saharan Africa was performed between September 2009 and December 2010. Several databases including EBSCO host, Academic Search Premier, Scopus, Science Direct, Google scholar and Web of Science, were searched for articles published in the English language. The search strategy used a combination of terms including: *infectious intestinal disease, aetiology (etiology) diarrhoea Africa, aetiology (etiology) gastroenteritis Africa, enteric infectious pathogen Africa*. Boolean operators (not, and, or) were also used in succession to narrow and widen the searches. Other articles were identified by reviewing the reference list of articles.

Criteria for selecting studies

Inclusion criteria

The primary selection was made based on the major topic of the article. The apriori-decided criteria used were the following:

- i) The age group of the study population must be clearly defined;
- ii) The study must define whether the subjects were clinically asymptomatic or symptomatic;
- iii) The study must include detailed results of

- microscopic analysis of stool samples and the number of samples tested must be reported;
- iv) The number of study subjects and positive results for both cases/controls must be reported;
- v) Only studies providing adequate information on the actual pathogens identified and prevalence rates for all pathogens identified and tested for three or more (≥ 3) pathogens were included.

Exclusion criteria

Studies were excluded if they focused on a single pathogen, did not include information

Table 1. Records excluded from study and reasons.

Reason	No. of studies	References
Full text not available	9	18-26
Non-clinical/non-human specimen tested	4	27-30
Only Travellers	4	31-34
Refugees and asylum seekers	2 (Full-text excluded)	35,36
Single pathogen focus	17 (8 Full-text excluded)	34,37-52
No aetiology data reported	4	53-56
Inadequate data	5	57-60
Others, Special populations	3	61-63
Reviews	4	64-67

Table 2. Summary of studies on gastrointestinal pathogens in Sub-Saharan Africa.

Location, author and date of publication	Setting, HIV prevalence, sample source	Participants age, study design	No. of specimen tested	Overall pathogen isolation rates
Guinea-Bissau: Bandim II & Belem of Bissau (2003) ⁶⁸	Peri-urban, community based	0-2 yrs; prospective cohort 2 yrs, follow-up	11987 cases	Pathogens found in 58% of specimen
Kenya 2: Kisumu (2009) ⁶⁹	Urban; HIV sero-prevalence was 13.6% amongst cases; hospital based	0-2 yrs; prospective Cohort 2 yrs, follow-up.	630 cases	Pathogens found in 32.2% of specimen.
Nigeria (1): Abakaliki (2008) ⁷⁰	Mixed setting; primary health care unit	0-4 yrs; retrospective study	150 cases 50 controls	Pathogens found in 81.3% of specimen
Nigeria (2): East Central State (1997) ⁷¹	Mixed setting; hospital based	0-5 yrs; retrospective study	1015 cases 401 controls	Pathogens found in 21.0% and 3.9% ($P < 0.001$) of cases and control specimen respectively
Zambia: Lusaka I (1998) ⁷²	Peri-urban; hospital based	0-5 yrs; retrospective study	639	Pathogens found in 29.9% of specimen.
Mozambique: Maputo province (2007) ⁷³	Rural, hospital based	0-5 yrs; retrospective study	529 cases	Pathogens found in 42.2% of specimen
Cameroon: Yaounde (2008) ⁷⁴	Urban, community based	0-5 yrs; retrospective study	3034 cases	pathogens found in 59.5% of specimen
Tanzania: Ifakara (2004) ⁷⁵	Urban; hospital based	0-5 yrs; retrospective study	451 cases	Pathogens found in 67.6% of specimen.
Ghana: Bulpelia / Tamale (2007) ⁷⁶	Urban, primary health care unit	0-11 yrs; case control study	243 cases, 124 controls	Pathogens found in 76.5% and 53.2% ($P < 0.001$) of cases and control specimen, respectively
Central African Rep. Bangui (1994) ⁷⁷	Urban, hospital based	0-15 yrs; retrospective study	1197 cases	Pathogens found in 49.4% of specimen
Zaire: Kinshasa (1994) ⁷⁸	Urban; hospital and health centre based	0-5 years; matched case control	173 cases, 155 controls	Pathogens found in 100% and 94% of cases and control specimen respectively
Zaire: Kivu (1983) ⁷⁹	Peri-urban; hospital based	0-5 years; case control	355 cases; 320 controls	Pathogens found in 40.3% and 14.1% of cases and control specimen respectively.
Nigeria: Lagos (1994) ⁸⁰	Urban; hospital and health centre based	0-5 years; case control	215 cases, 100 controls	Pathogens found in 74.9% and 28% of cases and control specimen respectively
Nigeria: Osun State (2003) ⁸¹	Urban; hospital based	0-5 years; retrospective study	135	Pathogens found in 100% of cases.
Nigeria: Abuja (2008) ⁸²	Peri-urban; hospital based	0-5 years; retrospective study	404	Pathogens found in 68.5% of cases.
Burkina Faso: Ouagadougou (2007) ⁸³	Peri-urban; HIV sero-prevalence = approx 10.6% amongst cases health centre based	0-5 years; retrospective study	66	Pathogens found in 42.4% of cases.
Ghana: Tamale (2008) ⁸⁴	Peri-urban; health centre based	0-11 years; case control	243 cases; 124 controls	Pathogens found in 92.6% and 86.3% of cases and control specimen, respectively.
Uganda: Kampala (2009) ⁸⁵	Peri-urban; HIV sero-prevalence = approx 24.7% amongst cases hospital based	0-5 years; retrospective study	190	Pathogens found in 24.7% of specimen.

Continued next page

on aetiology or did not provide adequate information about methods employed, or was not available in full-text among other reasons presented in Table 1.

Study selection, quality assessment and data extraction

The primary selection included any cross-sectional studies, case controls, and retrospective or prospective cohorts. Studies were selected if they included details of the number of samples tested, laboratory methods, results of analyses, and subjects' HIV status and the period of the study. The outcome of interest was the number and types of pathogens isolated from diarrhoeal and non-diarrhoeal stool specimens. All studies included were screened based on the MOOSE guidelines. Data were summarized based on location, study population and associated risk factors (Table 2). Microbiological analyses of stool specimen are summarized in Table 3.

Pooled data was analysed using the Comprehensive Meta-analysis programme,⁹⁵ based on the random effects (RE) model. This model assumes that the impact of covariates capture some but not all of the true variation among effects, hence the RE model is designed to take these differences into

account and makes the assumption that the effect size (pooled prevalence) is the mean of the true effect sizes for all studies with a given value of the co-variables.⁹⁶

Pooled data was stratified by age groups for analysis. Prevalence was reported with 95% confidence interval (CI), and odds ratios (OR) given where applicable. The random-effect method⁹⁷ was used in meta-analysis and heterogeneity between studies was calculated on the basis of the Cochran's Q-test. Heterogeneity among studies was considered significant if the P value of Cochran's Q-test was less than 0.05. The findings were interpreted in light of current knowledge and practice based on the previously outlined aims of the study.

Results

Studies identified

The initial search identified 198 articles, 66 of which were reviewed for inclusion, with 39 rejected for various reasons (Figure 1 and Table 1). After critical review, 27 articles were selected for this review. The methodology and summary of findings for each study,^{68-94,98-101}

are summarized in Table 2. The studies represented 14 countries in SSA. Different study designs were employed in the studies, including cross-sectional, case control and prospective follow-up cohort designs. The samples were obtained from persons seen in hospitals, primary health care centres or recruited in community cohorts, in urban, peri-urban and rural settings. Seventeen of the studies looked at children, six looked at adults (12-80+ years) and four looked at mixed age groups.

Microbiology

Stool samples were examined using standard parasitological (microscopy or direct observation), bacteriology (cultures), and virology techniques [mainly the enzyme-linked immunosorbent assay (ELISA) for rotavirus screening], presented in Table 3.

Pathogen isolation rates

The rate of isolating pathogens from cases varied widely between countries and between age groups, with an overall isolation rate of 55.7% (95% CI, 48.2-62.9%). Isolation of pathogens was highest amongst adult cases (mean 65.6%; 95% CI, 26.0%-91.2%) followed by children, (mean 58.1%; 95% CI, 50.1-65.6%) and mixed aged groups showed the lowest

Table 2. Continued from previous page.

Location, author and date of publication	Setting, HIV prevalence, sample source	Participants age, study design	No. of specimen tested	Overall pathogen isolation rates
Meta-analysis: random effects mean isolation rate in children: 58.1% (95% CI; 50.1-65.6%); heterogeneity P<0.046;				
Malawi: Lilongwe (1996) ⁸⁶	Urban; HIV sero-prevalence = approx 60% amongst controls; hospital based	≥12 yrs; case control study.	132 cases 73 controls	Pathogens found in 48.3% and 2% of cases and control specimen respectively.
Uganda: Entebbe (2002) ⁸⁷	Semi-urban; HIV sero-prevalence = approx 100% amongst cases and controls; community based	Adults (IQR = 26-36 yrs) Prospective Cohort, 2 yrs, follow-up	357 cases, 127 controls	Pathogens found in 49% and 39% of cases and control specimen, respectively
Zambia: Lusaka (2) (1996) ⁸⁸	Urban; HIV sero-prevalence = approx 97% amongst cases; community based.	18-79 yrs; retrospective study	77	Pathogens found in 78% of specimen
Zambia, Misisi, Lusaka (3) (2009) ⁸⁹	Urban; HIV sero-prevalence was 31% amongst cases; hospital based	18-79 yrs; prospective Cohort, 3 yrs, follow-up	4780	Pathogens found in 99% of specimen
Central African Republic, Bangui (1998) ⁹⁰	HIV sero-prevalence = approx 74% and 52% amongst cases and controls, respectively; hospital based	>18 years; case control	290 cases; 140 controls	Pathogens found in 55.5% and 61.4% of cases and control specimen, respectively
Meta-analysis: random effects mean isolation rate in adults: 65.6% (95% CI, 26.0-91.2%); heterogeneity P<0.454				
South Africa: Venda region (2003) ⁹¹	Rural; community based	All age groups; retrospective study	401 cases	Pathogens found in >95.3% of specimen (totals not given)
Burkina Fasa: Ouagadougou (2002) ⁹²	Rural; hospital based	All age groups; retrospective study	4131 (protozoa) 826 (bacteria)	Pathogens found in 8% of specimen, respectively
Kenya I: Asembo Bay (2006) ⁹³	Rural, community based	0-70+ years; retrospective surveillance type	3445 cases	Pathogens found in 31.7% of specimen
Kenya I: Asembo Bay (2003) ⁹⁴	Rural, health centre based	0-70+ years; retrospective surveillance type	451 cases	Pathogens found in 51% of specimen

Meta-analysis: random effects mean isolation rate in mixed-ages: 26.8% (95% CI, 11.3-51.3%); heterogeneity P<0.063. Overall random effects mean isolation rate for all age groups: 55.7% (95% CI, 48.2-62.9%); heterogeneity P>0.05. Q=5.806; df =2, P=0.055.

rates (26.8% (95% CI, 11.3%-51.3%) (Figure 2). Heterogeneity testing suggests slight differences between age groups ($Q=5.806$; $df=2$), but this was not significant ($P=0.055$). Eight studies reported HIV sero-prevalence rates ranging from 10.6%-100% amongst adult participants. When these studies were removed from the analysis the overall isolation rate was not significantly different (54.3%; 95% CI, 43.5%-64.7%). In ten studies where comparable asymptomatic controls were tested, there were significantly more pathogens isolated from cases than controls with a mean overall odds ratio (OR) of 4.93 (95% CI, 1.99-12.23),

ranging from 0.52 to 72.05. Very large differences between cases and controls of over 20 times higher isolation rates were observed in Malawi (39), OR 20.52 (95% CI, 2.73-154.24, Nigeria (42), OR 50.0 (95% CI, 16.63-150.36), and Central Africa Rep. (31) OR 72.05 (95% CI, 38.21-135.85).

Etiology data by category was collated from the details reported in each study (Figure 3). Bacterial pathogens (39.82%) were the most common group isolated in a majority of studies followed by parasites (27.11%) and viruses (21.95%).

On average, other diarrheagenic *E. coli* spp.,

(29.95%), ETEC (15.37%), *Shigella* spp. (10.49%), *Salmonella* spp. (8.36%), and *Campylobacter* spp. (8.33%), were the most common bacterial pathogens reported by 12, 9, 22, 21 and 17 studies, respectively. Non-cholera *Vibrio* spp., *Staphylococcus aureus* and *C. difficile* were reported by one study each (Table 4).

Rotavirus was by far the most common viral agent isolated in an average of 19.51% of cases, in 13 studies; with nearly half of these studies isolating it from 20% or more of cases (Figure 4). Adenovirus (9.2%) was reported by five studies, while astroviruses (5%) and

Table 3. Summary of microbiological tests done by studies on GI pathogens in sub-Saharan Africa.

Location and date of publication	Bacteriology methods	Virology methods	Parasitological methods
Guinea-Bissau: Bandim II & Belem of Bissau (2003) ⁶⁸	Standard culture methods, DNA-DNA hybridization	ELISA	Microscopy
Kenya 2: Kisumu (2009) ⁶⁹	Standard culture methods & bright-field microscopy	ELISA	Microscopy & IFA
Nigeria (1): Abakaliki (2008) ⁷⁰	Standard culture methods & direct microscopy	ELISA	Microscopy
Nigeria (2): East Central State (1997) ⁷¹	Standard culture methods	N/A	N/A
Zambia: Lusaka 1 (1998) ⁷²	Standard culture methods	N/A	N/A
Mozambique: Maputo Province (2007) ⁷³	Standard culture methods & direct microscopy	N/A	Direct observation & microscopy
Cameroon: Yaounde (2008) ⁷⁴	Standard culture methods	ELISA	Microscopy
Tanzania: Ifakara (2004) ⁷⁵	Standard culture methods & direct microscopy	Agglutination test	Direct observation
Ghana: Bulpelia / Tamale (2007) ⁷⁶	Standard culture methods	RT-PCR	Microscopy
Central African Rep. Bangui (1994) ⁷⁷	Standard culture methods	ELISA	Microscopy
Zaire: Kinshasa (1994) ⁷⁸	Standard culture & direct microscopy	Latex agglutination test	Direct observation & microscopy
Zaire: Kivu (1983) ⁷⁹	Standard culture methods	ELISA	Direct microscopy.
Nigeria: Lagos (1994) ⁸⁰	Standard culture methods	ELISA	Direct microscopy + iron haematoxylin staining for <i>Cryptosporidium</i> sp.
Nigeria: Osun State (2003) ⁸¹	Standard culture methods and plate dilution technique for antibiotic susceptibility testing.	N/A	N/A
Nigeria: Abuja (2008) ⁸²	Standard culture and slide agglutination technique; modified disc diffusion technique for antibiotic susceptibility testing.	EIA	Light microscopy & Ziehl-Neelsen (Kinyoun's) stain for <i>Cryptosporidium</i> .
Burkina Faso: Ouagadougou (2007) ⁸³	N/A	Immunochromatographic tests.	Direct microscopy
Ghana: Tamale (2008) ⁸⁴	Standard culture methods and breakpoint microdilution test for antibiotic susceptibility.	N/A	N/A
Uganda: Kampala (2009) ⁸⁵	Standard culture methods and disc diffusion technique for antibiotic susceptibility.	N/A	N/A
Malawi: Lilongwe (1996) ⁸⁶	Standard culture methods & direct microscopy.	N/A	N/A
Uganda: Entebbe (2002) ⁸⁷	Standard culture methods & direct microscopy.	N/A	Microscopy
Zambia: Lusaka (2) (1996) ⁸⁸	N/A	N/A	Light microscopy, electron microscopy and PCR
Zambia, Misisi, Lusaka (3) (2009) ⁸⁹	Standard culture methods & direct microscopy.	N/A	Microscopy
Central African Republic, Bangui (1998) ⁹⁰	Standard culture methods and disc diffusion technique for antibiotic susceptibility.	Latex agglutination test	Dark-field microscopy with staining
South Africa: Venda region (2003) ⁹¹	Standard culture.	ELISA	N/A
Burkina Faso: Ouagadougou (2002) ⁹²	Standard culture methods & direct microscopy.	N/A	N/A
Kenya I: Asembo Bay (2006) ⁹³	Standard culture and PCR for <i>E. coli</i> sp.	ELISA	Microscopy
Kenya I: Asembo Bay (2003) ⁹⁴	Standard culture methods and disc diffusion technique for antibiotic susceptibility.	N/A	N/A

ELISA, Enzyme-linked immuno-assay; EIA, enzyme immuno assay; PCR, polymerase chain reaction; IFA, immunofluorescence assay; N/A, not available.

norovirus (9.5%) were only reported in the Ghana 2005-2006 study. Intestinal parasites were isolated from an average of 25.9% of cases. The enteric protozoa *Cryptosporidium* spp. (21.52%), *Cyclospora* spp. (18%), *Entamoeba* spp. (13.8%), *Blastocystis hominis* (11.0%) were the most common. *Ascaris lumbricoides* was the most common helminthic infection reported in an average of 9.14% of cases, while several other pathogenic and non-pathogenic parasites reported in a few studies. In the study from Zambia (1994) which only tested for parasites in HIV positive adults, up to 78% of specimen were positive with a high prevalence of intracellular protozoa (*Cryptosporidium parvum*, *Cystoisospora* (isospora) *belli* and microsporidia).

Discussion

Diarrhoea continues to affect children and adults in African countries.^{2,4,11} Increases in diarrhoea rates over the period 1967 to 1997 have been seen in Kenya (6%-18%) and Uganda (16-21%), but reduction seen in Tanzania (11-8%)¹² and Malawi (20-14%) from 1992-2000.⁵⁶ While some countries have attempted to determine the prevalence and etiology of GI, most have looked at single pathogens.¹⁰² This review has confirmed and strengthened the view that there is a high rate of illness due to pathogenic enteric microorganisms affecting the region.

Eight of the studies reported HIV sero-prevalence rates amongst patients. The HIV sero-prevalence in some SSA countries is high and infected persons may have been included in some studies, but was not reported. All adult studies included HIV positive cases, but when these were removed from the analysis, there was no apparent difference in prevalence. While immuno-compromised persons are more susceptible to diarrhoeal illness, the pathogens are similar to those in immuno-competent persons, with differences mainly seen with opportunistic parasitic infections.^{87,103,104} Where higher rates are seen in immuno-compromised patients this may be due to the higher likelihood of seeking medical attention for their symptoms, and are more likely to be tested for pathogens.¹⁰⁵

Bacteria were the main pathogens identified by a majority of studies, and the high rates of diarrhoeagenic *E. coli* spp., *Shigella*, *Salmonella* spp., and *Campylobacter* spp., is consistent with the prevailing risk factors,^{9,11,106,107} and likely reflects the availability of bacteriological diagnostic techniques. Our study like many others confirm that pathogenic *E. coli* and *Shigella* dominate in developing countries,^{68,72,77,108} compared with *Salmonella*,

Shigella, and *Campylobacter* in industrialized countries.¹⁰⁹⁻¹¹¹ These pathogens are transmitted through mainly fecal oral route,¹¹²⁻¹¹⁵ and contaminated food or water.¹¹⁵⁻¹²³ In eleven studies, only one category of pathogen was

investigated, which is a limitation of such studies in estimating the overall burden of infectious pathogens.^{71,72,81,82,84,85,88,92-94,117}

Rotavirus was the most common virus isolated and reported in SSA. Worldwide,

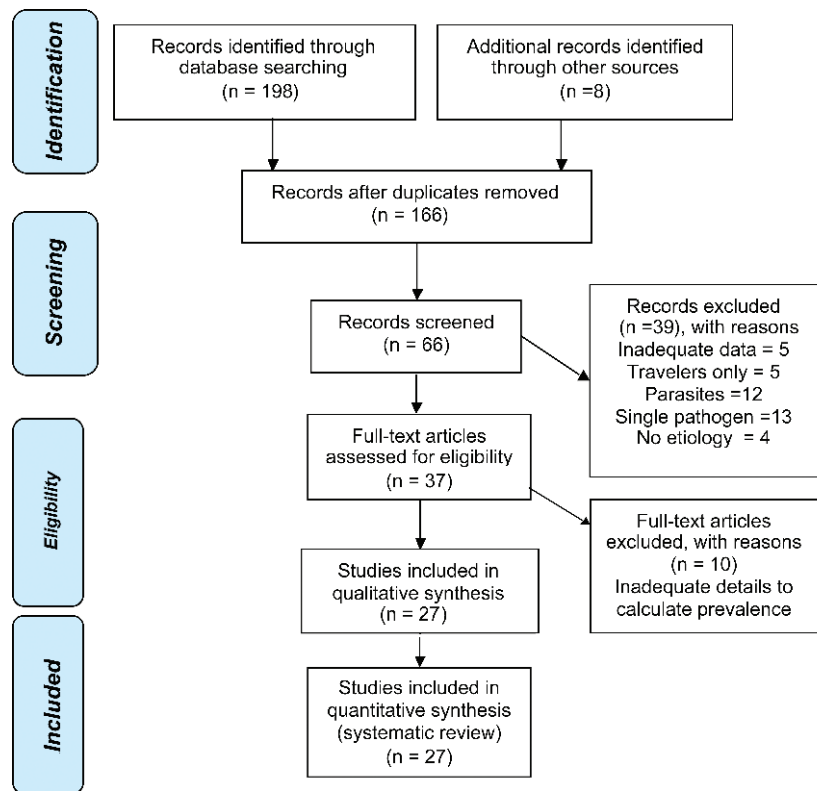


Figure 1. Identification and screening of studies for systematic review.

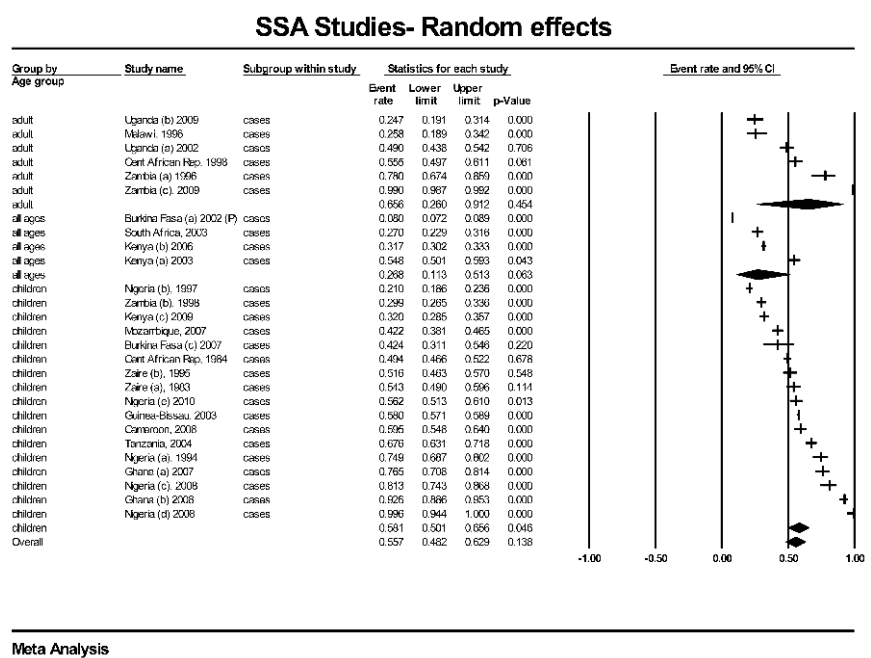


Figure 2. Rates of isolation of enteric pathogens in twenty seven Sub-Saharan African countries.

norovirus, rotavirus, and other caliciviruses represent over 80% of acute GI from known causes, affecting young children and the elderly.^{107,115,124-127} In both developing and developed countries rotavirus is the leading cause of viral gastroenteritis.^{68,74,77,108-110} A majority of children become infected with rotavirus by their third birthday,^{68,76,77,112,125,126,128} with the average age of onset in developing countries being lower than in children in developed countries.¹¹² Waterborne transmission is common, but risk of nosocomial infections in infants and newborns and in childcare settings increases once infection occurs.^{108,115} The epidemiology of norovirus on the other hand is different as it affects persons of all age groups and has become notorious for causing epidemics on ships, hotels and large gatherings.^{125,126,129}

High rates of parasitic infections have been found in SSA with *Cryptosporidium*, *Cyclospora* spp., and *Entamoeba* spp implicated as common parasites, and is consistent with findings from other developing settings, where sanitation and access to clean water is compromised.^{25,60,102,130} *Blastocystis hominis* was frequently isolated from diarrhoeal stools, but there are conflicting views about its role as a pathogen, and some laboratories may not place priority on looking for this parasite.¹³¹⁻¹³³ In addition, limited diagnostic capacity for protozoan pathogens may have influenced what is reported, and the true prevalence may be higher.^{25,133,134} Advanced biotechnological methods such as PCR will improve the diagnosis and understanding of intestinal parasites.^{132,134,135}

The presence of multiple parasite species is also common and this has further implications for diarrhoea related malnutrition and stunting.^{23,60,136-138}

Prevention and control

Many enteric pathogens are transmitted through similar exposures routes, hence community based multi-stage prevention measures will control several at the same time. Improved sanitation, drinking water quality and hygiene measures have proven to decrease the incidence of diarrhoeal disease by at least 1/3.^{8,139} There is evidence that hand hygiene alone can reduce incidence by 31-47%,^{140,141} while low cost household treatment, safe storage and improved water quality can reduce incidence by about 25-35%.¹³⁹ Except some protozoa, the enteric pathogens are easily controlled by chlorination of water, which can be done at the household level,^{14,142} supplemented by safe storage and use.¹³⁹

Public Health significance

The high prevalence of gastrointestinal pathogens in SSA suggests the presence and

high risk of exposure to environmental risk factors. Risk factors must therefore be tackled head-on, if countries in SSA are to achieve the target of reducing child deaths by two thirds by the year 2015. Public health programmes must therefore be given priority by governments, with policies supported by sufficiently well trained personnel, modern equipment and legislation. Many countries have the will, but with diarrheal diseases competing with other programmes for scarce resources, the degree of the impact of small interventions can hardly be felt. Currently, less than 5% of funding for research and development goes into diarrhoeal disease.¹⁴³⁻¹⁴⁵

Conclusions

This review is the first looking at the range of infectious enteric pathogens circulating in SSA, and confirms high rates of isolation of pathogens from diarrhoeal cases; while age related differences were observed and some looked at one category of pathogen, the quality of those included was assured by the peer review process.

Further studies are needed to quantify the prevalence and types of pathogens in circulation in SSA. Public health practitioners can use this information to understanding the

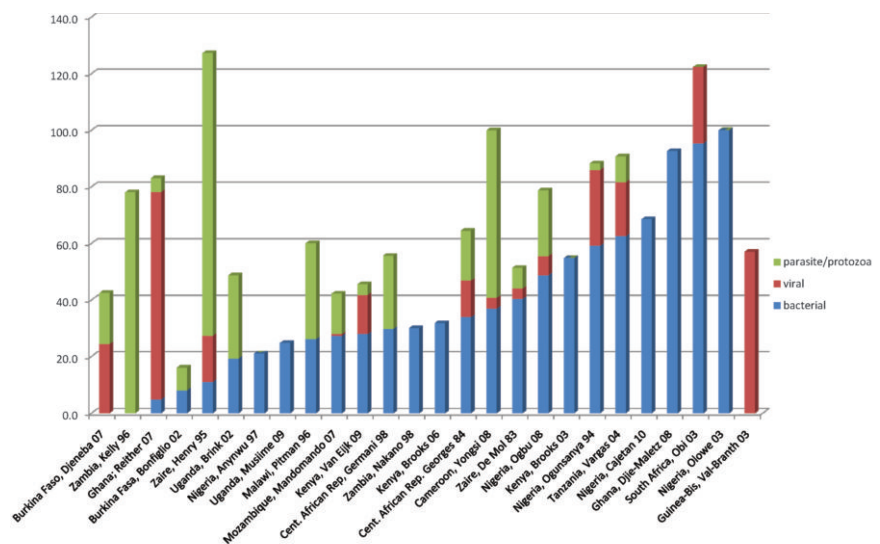


Figure 3. Prevalence of pathogenic bacteria, virus and parasites isolated in twenty seven Sub-Saharan African countries.

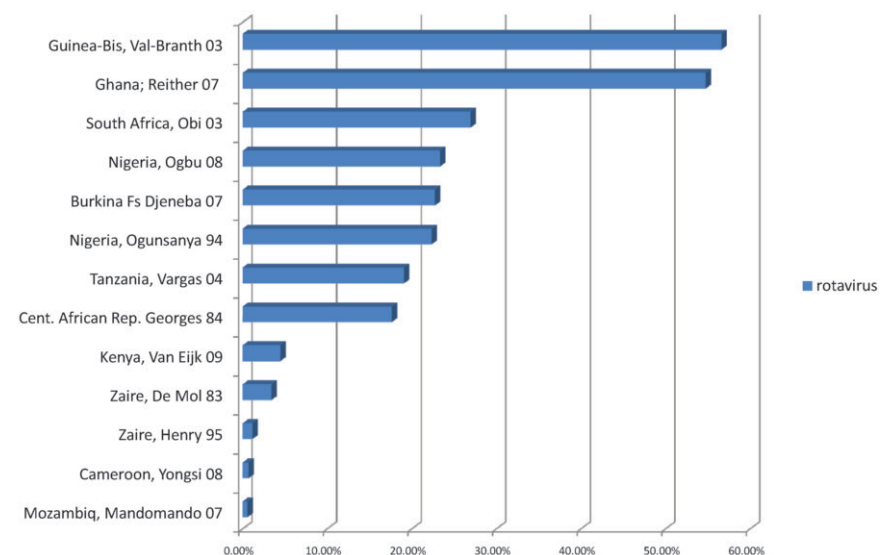


Figure 4. Rates of isolation of rotavirus in thirteen sub-Saharan African Countries.

Table 4. Rates of isolation of bacterial pathogens in diarrhoea cases in sub-Saharan African countries.

Countries	<i>Aeromonas</i> spp.	<i>C. jejuni</i>	Enteropathogenic <i>E. coli</i>	Enterotoxigenic <i>E. coli</i>	Other <i>E. coli</i> sp.	<i>P. shigelloides</i>	<i>Salmonella</i> spp.	<i>Shigella</i> spp.	<i>Vibrio cholerae</i> spp.	<i>Yersinia</i> spp.
Ghana, 2007	N/R	0.82%	N/R	N/R	N/R	N/R	2.47%	1.65%	N/R	N/R
Cameroun, 2008	N/R	5.72%	1.37%	2.50%	2.75%	N/R	5.72%	4.35%	N/R	N/R
Cent. African Rep. 1984	N/R	10.65%	3.43%	12.10%	N/R	N/R	4.85%	2.67%	N/R	N/R
Malawi, 1996	N/R	N/R	N/R	N/R	N/R	N/R	N/R	24.24%	N/R	N/R
Tanzania, 2004	0.67%	2.00%	N/R	N/R	35.70%	0.67%	1.11%	21.51%	N/R	N/R
Nigeria, 2008	N/R	2.67%	N/R	N/R	15.33%	N/R	11.33%	3.33%	N/R	3.00%
Burkina Faso, 2002	N/R	N/R	N/R	N/R	34.02%	N/R	N/R	10.05%	N/R	4.00%
Kenya, 2003	N/R	8.65%	N/R	N/R	N/R	N/R	5.25%	15.94%	4.00%	N/R
South Africa, 2003	8.48%	19.70%	2.49%	7.50%	10.22%	10.72%	14.46%	12.47%	4.00%	5.00%
Mozambique, 2007	N/R	1.70%	6.81%	4.30%	11.53%	N/R	2.46%	0.19%	N/R	N/R
Zambia, 2009	0.36%	N/R	N/R	N/R	N/R	N/R	1.21%	0.38%	N/R	N/R
Uganda, 2002	N/R	4.76%	N/R	N/R	N/R	N/R	10.92%	12.89%	N/R	N/R
Zambia, 1996	N/R	N/R	N/R	N/R	14.87%	N/R	1.41%	10.17%	3.00%	N/R
Guinea-Bis, 2003	N/R	35.18%	95.02%	N/R	N/R	N/R	56.76%	29.05%	N/R	N/R
Nigeria, 1997	N/R	2.46%	N/R	12.00%	N/R	N/R	3.05%	2.07%	1.00%	N/R
Kenya, 2009	N/R	20.79%	N/R	N/R	N/R	N/R	3.49%	5.40%	N/R	N/R
Zaire, 1983	N/R	16.06%	9.01%	3.40%	N/R	N/R	2.54%	1.97%	6.00%	1.00%
Zaire, 1995	N/R	0.58%	N/R	6.90%	N/R	N/R	3.47%	N/R	N/R	N/R
Cent. African Rep, 1998	N/R	1.72%	1.03%	N/R	10.00%	N/R	10.00%	N/R	N/R	N/R
Ghana, 2008	N/R	0.82%	N/R	N/R	87.65%	N/R	2.47%	1.65%	N/R	N/R
Ghana, 1994	1.40%	N/R	14.42%	10.70%	14.42%	N/R	3.26%	5.12%	N/R	1.00%
Nigeria, 2003	N/R	7.32%	N/R	N/R	N/R	N/R	3.33%	43.30%	N/R	N/R
Nigeria, 2003	N/R	N/R	N/R	N/R	77.78%	N/R	N/R	16.30%	N/R	N/R
Nigeria, 2010	N/R	N/R	N/R	N/R	43.07%	2.72%	2.23%	N/R	N/R	N/R
Uganda, 2009	N/R	N/R	4.74%	8.90%	2.11%	N/R	5.79%	3.16%	N/R	N/R

N/R, not reported.

challenges related to GI pathogens and set priorities for prevention programmes, and develop multi-stage prevention strategies for increased overall effectiveness.

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