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What is the cost? Pediatric cryptosporidiosis in Peru, Bangladesh, and Kenya

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Introduction

- *Cryptosporidium* is an intestinal protozoan parasite that is a major cause of diarrheal disease among young children in low-resource settings (References 1 and 2).
- Beyond diarrheal disease, cryptosporidiosis is associated with other chronic conditions, including growth faltering, environmental enteric dysfunction, and possibly impaired cognitive development (Reference 3).
- The economic burden of cryptosporidiosis has been poorly characterized, in particular the long-term and indirect effects.

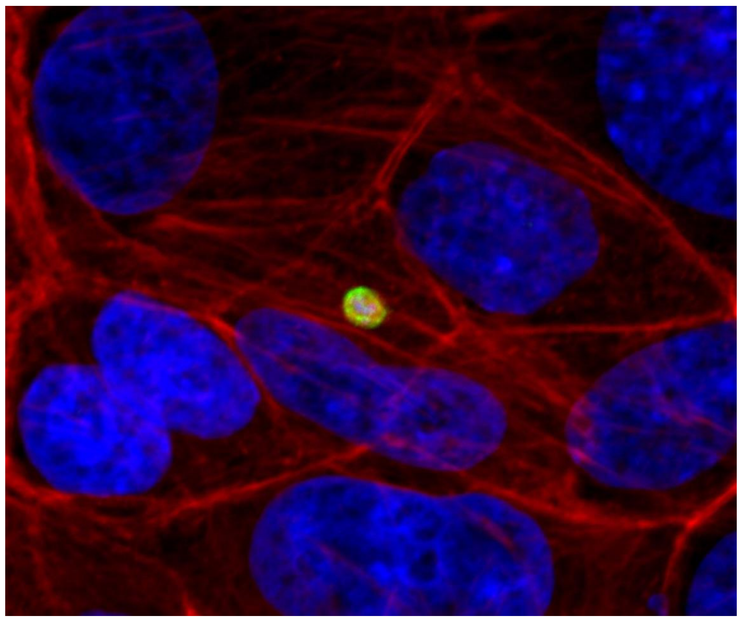

Figure 1. Fluorescence micrograph of *Cryptosporidium* (yellow) perched on the periphery of an infected intestinal epithelial cell (blue = nuclei, red = cytoskeleton).
Image courtesy B. Striepen (unpublished).

Objectives

1. Comprehensively describe the economic impact of cryptosporidiosis on families and society in low-resource settings.
2. Identify data gaps to inform objectives for future economic analyses.

Methods

- The input data that were used to calculate the economic burden of cryptosporidiosis on Kenya as a representative example are shown in Table 1. Similar data were acquired for Bangladesh and Peru. These three countries were selected because they were representative of their respective continents and because of the existence of adequate data from previous studies.
- We focused on children under 1 year of age, as they are the most severely impacted by *Cryptosporidium*. Preliminary analyses suggested that the economic burden of cryptosporidiosis was minimal in children older than 1 year of age.
- Age-specific diarrhea cases attributable to *Cryptosporidium* were derived from the Global Enteric Multicenter Study (GEMS; Kenya and Bangladesh) and the Malnutrition and the Consequences for Child Health and Development Project (MAL-ED; Peru) data (References 1 and 2).
- We accounted for both direct and indirect costs of the disease from various sources including:
  - Health Utilization and Attitudes Surveys. (Reference 1)
  - Vaccination cost-effectiveness analysis. (Reference 5)
  - Reports on in-country health care cost. (Reference 6)
  - Pharmacy data and household surveys. (References 7 and 8)
- Direct costs included:
  - Health practitioner fees.
  - Diagnostic tests.
  - Drug and oral rehydration solution (ORS) costs.
  - Transportation to seek care.
- Indirect costs included:
  - Caregiver income loss.
  - Lost lifetime earnings due to morbidity (e.g., permanent growth faltering) and mortality.

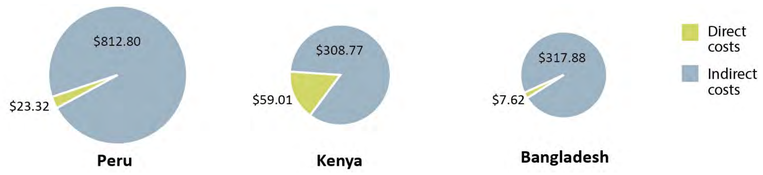

Figure 2. Comparison of direct and indirect medical costs per case of cryptosporidiosis in 2016 international dollars. Direct costs were highest in Kenya, primarily due to higher costs of inpatient care and larger percentage of individuals seeking inpatient care. Indirect costs were highest in Peru, due to higher average income and longer average life expectancy.

Results

- Peru had the highest incidence of cryptosporidiosis in the first year of life, followed by Kenya and Bangladesh.
- Mortality in the first year of life was highest in Kenya, followed by Bangladesh, and lowest in Peru.
- Health care–seeking behavior differed by country, with variations in the type of care sought (formal versus informal) and the percentage of caregivers who accessed each type of care for their children.
- Peru had the highest total economic burden, despite having the smallest cohort population and lowest mortality rate. Total costs are summarized in Table 2.
- Sensitivity analysis showed a wide variation in the best- and worst-case scenario estimates. The ranges were driven largely by uncertainty in disease incidence, scarcity of data that quantify growth faltering attributable to *Cryptosporidium*, and frequency of faltered growth persisting into adulthood.
- Uncertainty relating to direct costs had little influence on overall costs in Bangladesh and Peru, whereas in Kenya, a wide range of inpatient costs is known to occur.

Table 1. Parameters of the pediatric cryptosporidiosis economic burden model (adapted from reference 4).

KENYA			
Parameter	**Base case**	**Low estimate**	**High estimate**
Disease and population estimates			
Population (0–11 months)	1,447,995	-	-
Incidence MSD attributable to *Cryptosporidium* (#/person-year; 0–11 months)[1]	0.04	0.02	0.072
Diarrhea severity (% of total)			
- MSD	- 55	- 53	- 58
- LSD[1]	- 45	- 47	- 42
Health care seeking behaviour and direct costs			
Diarrhea cases who seek outpatient care (%)	44	34	54
Diarrhea cases who seek inpatient care (%)[1]	18	12	25
Diarrhea cases who visit a pharmacist (%)	34	31	36
Diarrhea cases visiting a pharmacist who receive (%):		-	-
- Antibiotics	- 51		
- ORS	- 43		
- Anti-motility	- 10		
- Zinc	- 8		
Outpatient cost ($/visit)[1]	25.24	12.69	85.18
Inpatient cost ($/visit)[1]	254.89	57.77	1,621.95
Inpatient length of stay (days)	3	2	5
Drug prices (median, $)		-	-
- Antibiotics	- 1.39		
- ORS	- 1.25		
- Anti-motility	- 0.57		
- Zinc	- 3.90		
Outpatients who pay for travel (%)	36	-	-
Inpatients who pay for travel (%)	77	-	-
Outpatient travel cost ($)	0.0	0.0	0.35
Inpatient travel cost ($)	10.65	8.48	13.05
Indirect costs			
Outpatient work days lost (days)	1	0	2
Inpatient work days lost (days)[1]	3	2	5
Caregiver wage ($/day)	5.09	-	-
Cryptosporidiosis mortality rate per 100,000 (0–364 days[1])	21.61	0.32	62.62
Life expectancy (years)	61.6	-	-
Labour force participation (%)	67.4	-	-
Annual income (average, $/person)	3,208.07	2,735.27	9,058.21
Stunting attributable to cryptosporidiosis (%)[1,2]	8.8	3.8	17.6
Stunted growth persisting into adulthood (%)[1]	22.9	10	64.6
Income lost from stunted growth (%)	20	10	30
Age of entry into the workforce (years)	15	-	-

All costs are presented in 2016 international dollars; base case determined from best estimates available; low and high estimates provided for pre-selected variables included in sensitivity analysis; MSD = Moderate to Severe Diarrhea, LSD = Less Severe Diarrhea, ORS = Oral Rehydration Salts
[1]Variables included in one-way sensitivity analysis
[2]Stunting and age of entry into the workforce parameters were uniform across countries

Table 2. Total costs associated with pediatric cryptosporidiosis in 2016 international dollars (adapted from Reference 4)

	Kenya	Bangladesh	Peru
Cryptosporidiosis cases (#/year)	121,105	30,251	51,085
- Number deaths	- 312	- 76	- 1
- Number stunted	- 2,443	- 610	- 1,030
Total direct costs ($)	7,146,611	230,564	1,191,343
- Outpatient	- 1,344,729	- 90,045	- 707,603
- Inpatient	- 5,556,374	- 77,554	- 468,949
- Travel	- 178,833	- 34,098	- 14,791
- Other[1]	- 66,67	- 28,867	- 0
Total indirect costs ($)	30,246,389	9,385,932	40,331,497
- Caregiver income loss	- 1,292,238	- 49,279	- 146,769
- Stunted growth	- 17,652,388	- 5,728,064	- 40,068,197
- Mortality	- 11,301,563	- 3,608,590	- 116,531
Costs per case ($)			
- Direct	- 59.01	- 7.62	- 23.32
- Indirect	- 308.77	- 317.88	- 812.80
Best case scenario ($)	1,606,495	277,312	883,807
Worst case scenario ($)	804.5M	91.5M	599.3M
Total societal costs ($)	**37.4M**	**9.6M**	**41.5M**

[1]Other includes costs for drugs, informal care and insurance

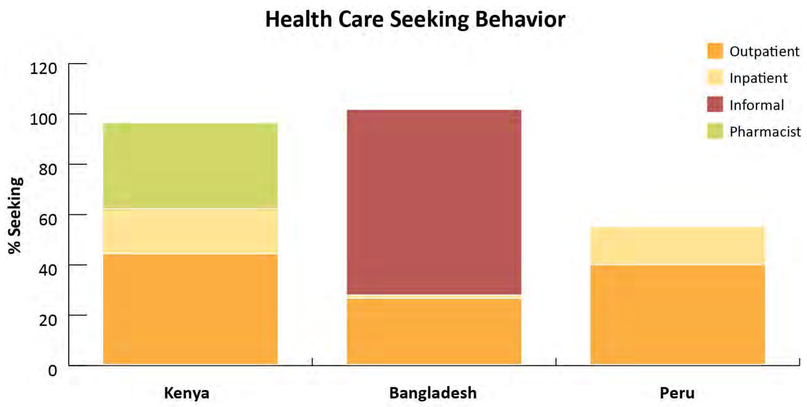

Figure 3. Comparison of health care–seeking behavior among three target countries.

Conclusions

1. Our economic analysis demonstrated that *Cryptosporidium* causes a significant burden both at the individual household level and for society as whole. *Cryptosporidium*-specific technological innovations and policy interventions suitable for resource-limited areas will be necessary to reduce this burden and achieve development goals.
2. The economic burden associated with long-term sequelae of pediatric cryptosporidiosis such as growth faltering, malnutrition, and cognitive impairment remains under-investigated.

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