The Epidemiology of Acute Gastrointestinal Illness in Ethiopia, Mozambique, Nigeria, and Tanzania

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

The three manuscripts presented in this thesis, that have been prepared to be or submitted, are the work of Binyam Desta, in collaboration with his co-authors and committee members:

Chapter 2: Epidemiology of Acute Gastrointestinal Illness in Ethiopia, Mozambique, Nigeria, and Tanzania. Prepared to submission to Epidemiology and Infections Journal (May 30, 2022).

- As lead author of this chapter, I led conceptualization of the study design and designed the data collection platform. I developed data collection training manual and trained the enumerators, coordinated the survey implementation, performed data extraction/ manipulation and carried out data analysis, and drafted the manuscript. Dr. Shannon Majowicz, Dr. Warren Dodd, and Dr. Sara Pires provided overall direction and editorial guidance throughout.

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- As a lead author of this chapter, I led conceptualization of the paper, and I drafted the manuscript. My co-authors provided feedback on the manuscript; co-authors are Tesfaye Gobena (Haramaya University), Custodia Macuamule (Eduardo Mondlane University), Olanrewaju E. Fayemi (Mountain Top University), Christianah I. Ayolabi (Mountain Top University, University of Lagos), Blandina T. Mmbaga (Kilimanjaro Clinical Research Institute, Kilimanjaro Christian Medical University College), Kate M. Thomas (Kilimanjaro Clinical Research Institute, University of Otago), Warren Dodd (University of Waterloo), Sara M. Pires (Technical University of Denmark), Shannon E. Majowicz (University of Waterloo), and Tine Hald (Technical University of Denmark). Dr. Shannon Majowicz, Dr. Warren Dodd, and Dr. Sara Pires contributed to the conceptualization and editing.

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- As lead author of this chapter, I led the conceptualization of the study design and data analysis. I performed data manipulation and carried out data analysis and drafted the manuscript. My co-authors provided targeted methodological guidance and feedback on draft manuscripts; co-authors are Sylvia Ota (Toronto Public Health), Effie Gournis (Toronto Public Health), Sara M. Pires (Technical University of Denmark), Amy L. Greer (University of Guelph), Warren Dodd (University of Waterloo), and Shannon E. Majowicz (University of Waterloo). Dr. Shannon Majowicz, Dr. Warren Dodd, and Dr. Sara Pires provided overall direction and editorial guidance throughout.

ABSTRACT

Gastrointestinal infections transmitted by food are a global concern and most severe in African low-and-middle-income countries (LMICs), though in these countries accurate data on acute gastrointestinal illness (AGI) are lacking. The thesis aimed to estimate the epidemiology of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania; because this research was interrupted by the COVID-19 pandemic, a secondary aim was to explore application of methods typically used to adjust for under-reporting of foodborne infections to COVID-19. The thesis objectives were to: describe the epidemiology of AGI at the population level in Ethiopia, Mozambique, Nigeria, and Tanzania; evaluate the multi-national collaborative process used to achieve the first objective; and apply methods used for foodborne infections to estimate the under-ascertainment multipliers for each step in the reporting chain for COVID-19 for an example setting with available data (Toronto, Canada). To determine the epidemiology of AGI, a population survey was conducted in one urban and one rural site in each of Ethiopia, Mozambique, Nigeria, and Tanzania, from October 01, 2020 to September 30, 2021, using both web-based and face-to-face survey tools (n=4487). The incidence of AGI (0.5 episodes per person-year) was comparable or lower to other LMICs, the duration (4 days) appeared slightly longer or comparable to other LMICs, and although age was a significant risk factor, gender was not. The multi-national collaboration that supported this population survey was evaluated using Larkan et al.'s (2016) framework and its seven core concepts: focus, values, equity, benefit, communication, leadership, and resolution. The evaluation identified that the partnership considered the interplay and balance between operations and relations, and featured a shared goal, mutual benefits, transparency, inclusiveness, and leadership attributes. A slight working culture difference was noted, with a need to enhance responsibility-sharing and dedication. Finally, application of foodborne underreporting

adjustment methods to COVID-19 was done for Toronto, Canada, where all necessary data sources (de-identified reported case data, weekly testing data, and population survey data) were available. Specifically, stochastic modelling was applied to estimate the under-ascertainment rate of COVID-19 in Toronto at early stages from March 2020 (the beginning of the pandemic) through May 23, 2020. Overall, 1 in 18 COVID-19 infections that occurred in the community were reported to Toronto Public Health. The under-ascertainment approach yielded comparable estimates to seroprevalence studies, and this approach allowed identification of where cases were lost in the reporting chain. In conclusion, this thesis identified that in Ethiopia, Mozambique, Nigeria, and Tanzania, AGI appears to pose a considerable incidence that suggests regular surveillance and intervention are needed. Future population surveys or other collaborative burden of infectious disease studies in African or other LMICs may benefit from partnerships that consider the interplay and balance between operations and relations and leadership attributes (and their dependent resolution strategies) such as the full and equitable delegation of tasks that eliminated hierarchical positionality and the flexibility to altering some premade decisions and executing action points. Finally, the COVID-19 pandemic provided an opportunity to apply the under-ascertainment measurement approach used for foodborne infections and influenza to COVID-19, and this thesis demonstrated that the under-ascertainment method typically applied to foodborne infections is useful for other infectious diseases under public health surveillance.

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LIST OF ABBREVIATIONS

AFR D	Africa region, stratum D
AFR E	Africa region, stratum E
AGI	Acute Gastrointestinal Illness
CHWs	Community Health Workers
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
DALYs	Disability-Adjusted Life Year
DHS	Demographic and Health Survey
FOCAL	Foodborne disease epidemiology, surveillance, and control in African LMIC
HEWs	Health Extension Workers
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome
LMICs	Low- and Middle-Income Countries
PCA	Principal Component Analysis
PCR	Polymerase Chain Reaction
PI	Principal Investigator
qPCR	Real-time Polymerase Chain Reaction
RT-PCR	Reverse Transcriptase Polymerase Chain Reaction

rRT-PCR	Real-time Reverse-Transcriptase Polymerase Chain Reaction
TB	Tuberculosis
TPH	Toronto Public Health
UI	Uncertainty Interval
US	United States of America
WHO	World Health Organization

Chapter 1

Introduction and Literature Review

1.1 Background

The world has faced a challenge from high-level morbidity and mortality due to gastrointestinal infections transmitted by food [1]. Globally, out of ten people, one becomes sick from eating contaminated food each year, and 420 000 of them die [2]. Consequently, about 33 million Disability Adjusted Life Years (DALYs) result from these illnesses [3,4]. High- and low- and middle-income countries are suffering from the burden of AGI, but at a different scale. Low and Middle-Income Countries (LMICs) are severely affected by the burden of AGI [5,6]. Africa bears the highest burden of foodborne illnesses compared to any other region, with 100 million foodborne infections and 140 000 deaths each year, illustrated by the 1 in 10 children and 1 in 13 all-ages deaths caused by diarrhea [2,5].

The available aggregate-level estimates in Africa indicate that the diarrheal disease burden estimate is 42,236 DALYs per 1000 population, which is higher than the burden estimate of malaria, preterm birth complications, and tuberculosis [2,7]. More significantly, the diarrheal illness burden in Africa is comparable to HIV/AIDS [2,7]. The African LMICs, including Ethiopia, Mozambique, Nigeria, and Tanzania, shared the burden [2].

However, in African LMICs, accurate data on acute gastrointestinal infections (AGIs) are lacking. The World Health Organization (WHO) (2015) estimated 824 and 147 DALYs per 100, 000 population from diarrheal and invasive infectious disease agents, respectively, in African countries, referred to as AFR E and AFR D (representing WHO's sub-regions classified based on the child and adult mortality) [3,4]. However, the WHO (2015) estimates are only sub-regional estimates based on imputation from countries with available reports [4,7–10]. Accordingly, the

variation in data availability and quality from the African LMICs requires the careful usage of these aggregate level estimates [3,8,11–16].

Many countries have done population surveys to study the epidemiology of AGI [17–24], and only two studies were found at the general population level in Africa: one study in an indigenous community in Uganda [25] and another in an urban setting in South Africa [26]. Available findings from the recent Demographic and Health Surveys (DHS) reports of Ethiopia, Mozambique, Nigeria, and Tanzania show under-five children diarrheal (two-weeks recall period) prevalence ranged from 10 to 12% [27–30]. The few studies on AGI in LMICs that focus on children and use a two-week recall period found a prevalence ranging from 6% to 22% [31–39]. However, as most epidemiology of diarrhea studies are centred on under-five children, there is a knowledge gap at the general population level in African LMIC. Moreover, having incomparable (i.e., 2-week versus 4-week recall; varying use of case definition) national incidence/prevalence estimates: limit the nation's ability to compare its achievements on the control of AGI on an international basis; make it difficult to contribute to international research collaborations; could affect the country when international-level policies are made [3,13,40–42].

Although there is a lack of accurate data on the characterization of diarrhea in African LMICs, particularly at the country level, the evidence illustrates that these countries suffered from a high AGI burden [43–48]. Thus, characterizing the epidemiology of AGI is critical and urgent to reduce the disease burden [46,49,50]. Moreover, information on the demographic determinants of AGI will guide intervention targets and strategies in response to intervention programs' effectiveness and resource constraints [51–55].

The thesis aimed to estimate the epidemiology of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania, with a goal that the findings will form a basis for the design of surveillance of

acute-infectious diarrheal illnesses and prioritization of intervention activities in the four African LMICs. Since this research was interrupted by the COVID-19 pandemic, a secondary aim was to explore the application of methods typically used to adjust for under-reporting of foodborne infections [56–58] to COVID-19. This thesis follows a manuscript style with three objectives. First, I aimed to describe the epidemiology of AGI in the general population in Ethiopia, Mozambique, Nigeria, and Tanzania, specifically to estimate the incidence, prevalence and duration of AGI and identify demographic determinants. Second, I evaluated the multi-national collaborative process used to achieve the first objective, intending to improve the team's efforts as well as inform future collaborations, thereby providing insights into the practicability of the burden of disease studies in African settings. For the third manuscript, I applied methods used for foodborne infections to estimate the under-ascertainment multipliers for each step in the reporting chain for COVID-19 for an example setting with available data (Toronto, Canada).

1.2 Literature Review

The Global and Regional (African) Burden of Acute Gastrointestinal Illnesses

Globally, there were 550 million (95% uncertainty interval – UI: 370 – 888 million) foodborne cases from infectious AGI estimated for 2010, of which 120 and 96 million cases are from *Norovirus* and *Campylobacter*, respectively. There were also 230,000 (95% UI: 160000 – 323000) deaths from foodborne illnesses estimated, caused by diarrheal disease agents. Of the total foodborne illness burden, more than half (18 million DALYs) were attributable to diarrheal disease agents [2]. AGI in general resulted in 1.31 million (95% UI: 1.23 – 1.39 million) deaths, globally, in 2015. These numbers put diarrhea as the leading cause of death among all ages combined. About 72 million (95% UI: 66 – 77 million) DALYs are caused by diarrhea, making diarrhea the leading cause of DALYs [59].

In Africa, the median rate estimate of foodborne illnesses caused by diarrheal disease agents was 9,830 per 100,000 persons (95% UI: 3,969 – 21,567 per 100,000 persons). The median death rate from foodborne illnesses and diarrheal disease agents (agents including *Vibrio cholera*, *Enteropathogenic E.coli*, and *Salmonella enterica*) were 14 and 9 per 100,000 persons, respectively [5]. Two African sub-regions of WHO, referred to as AFR-D and AFR-E, bear the highest burden of foodborne illness compared to other sub-regions of the world. The WHO Foodborne Disease Burden Epidemiology Reference Group defined these sub-regions considering child and adult mortality, which forms the letter suffixed to the acronym representing Africa of the WHO six regions (AFR: AFR D includes Nigeria, and AFR E include Ethiopia, Mozambique, Tanzania) [2]). AFR D and AFR E bear 1300 and 1200 DALYs per 100,000 population, and diarrheal disease agents are the cause for around 70% of the foodborne illness [3,4]. In Africa, AGI caused 4141 DALYs per 100,000 population in 2016; this is higher when compared to the burden caused by malaria (3400 DALYs), preterm birth complication (3149 DALYs), and tuberculosis (3149 DALYs) per 100,000 population. Above all, the diarrheal disease burden was also comparable to the burden caused by HIV/AIDS (4258 DALYs per 100,000 population) [7].

From these WHO estimates it is evident that foodborne illness and AGI are critical problem across African countries; however, it is worth noting that these WHO estimates are sub-regional aggregate level estimates that relied on the data from nation-based disease registries [3,4,7,8,10]. The disease surveillance system, in the African LMICs context, provides limited data, which evidently could result in an under- or over-reporting of the WHO estimates. The surveillance systems in LMICs encounter various challenges, including lack of adherence to guidelines, lack of political commitment and monitoring, lack of continuous capacity building, inconsistent case definitions, resource constraints, and inadequate laboratory facilities and data collection tools

[3,10,12,15]. Because the data available possibly varied between countries, the aggregate level WHO estimates could misrepresent the epidemiological characteristics of foodborne illness or AGI in the African LMICs [8,10,11,14,16]. Therefore, every nation needs an accurate description of the epidemiology of AGI, so as to enable informed intervention decisions and policy-making [3,10,16,42].

In this regard, most high-income countries have national estimates of the occurrence of AGI, as depicted in the Table A1 (see Appendix A). These estimates from high-income countries would not be suitable to extract and infer to LMICs as the population characteristics differ significantly [60]. However, these studies in high-income countries are helpful to informing the design and conduct of similar studies within the context of the LMICs.

There are few studies on AGI in LMICs, from which I extracted the information in the following sections; however, studies on AGI in LMICs focus on children [47,61–64]. Based on a multilevel analysis of DHS data from 40 multi-region LMICs, a study reports 14% two-week AGI prevalence among children under five years of age [63]. A review paper on population-based studies in five LMICs (i.e., Bangladesh, Ethiopia, Pakistan, Uganda, and Tanzania) showed that AGI accounts for 2.8% - 22.3% of all the deaths among children aged one to fifty-nine months, from 2003 to 2011 [43]. According to studies in non-African LMICs, Myanmar and countries in Mesoamerica, the 2-weeks AGI prevalence ranged from 4.47% to 13%, among children the age of five [65,66].

In particular, in African LMICs, AGI-related investigations are focused on children, except for two studies conducted in a rural community of Uganda and urban settings of South Africa, where the population level two-week AGI prevalence were 6.2% and 5.3%, respectively [25,26]. Based on studies in five African LMICs (i.e., Burundi, Senegal, Mauritania, South Africa, and

Kenya), the 2-weeks AGI prevalence ranged from 13% to 32.6% among children less than five years old [67–71]. In line with this, studies in Ethiopia, Mozambique, Nigeria, and Tanzania reported AGI prevalence ranged from 6.1% to 27.2% among children below the age of five years; which the prevalence range included 1- to 2-weeks recall and represented different study settings (i.e., rural, urban, or both) [32,35–39,72–75]. A meta-analysis study also shows a pooled AGI prevalence of 22% (95%CI: 19% - 25%) among children aged five years or below in Ethiopia [31]. The recent DHS in Ethiopia, Mozambique, Nigeria, and Tanzania estimated prevalence of 2-weeks recall ranged from 10% to 12% among children aged five years or below (refer to Table A2 in Appendix A) [27–30].

As indicated above, findings from the AGI studies in high-income countries would be unrealistic to infer to LMICs countries [60]. The majority of the AGI-related studies in LMICs focused on children and few in non-African LMICs, only two studies were found at the general population level in Africa: one study in an indigenous community in Uganda [25] and another in an urban setting in South Africa [26]. The case definitions of AGI in these studies vary in the extent or scope, and for the sake of a comprehensive review of the literature, I chose to review and categorized studies as reporting 2- and 4-weeks incidence/prevalence of AGI. For this thesis, I mainly reviewed and extracted findings on AGI in LMICs, as presented in the following sections. However, all these studies about AGI all over the world could inform the design of a study in the African LMICs, as elaborated in the section below.

Methodological Framework to Characterize the Epidemiology of AGI

Based on publications since 2004, studies about AGI throughout the world used different designs, including retrospective cross-sectional population-based surveys, prospective cohort studies, and intervention trials [76]. In high-income countries, most of the recent studies used

retrospective, cross-sectional population surveys to study the occurrence of AGI. These surveys relied on self-reported information, and the data collection methods included telephone interview, face-to-face interview, or mailing self-administered questionnaire (see Table A1 in Appendix A). There were also studies in high-income countries that used prospective population cohort and longitudinal survey designs [77,78]. Almost all AGI studies conducted in LMICs employed retrospective, cross-sectional population surveys using a face-to-face interview data collection method [23,24,79–94]. The studies that employed the prospective population cohort study design were few, and this might be related to the fact that such designs would add more complexity to the conduct of a study and incur more cost [95]. Compared with other descriptive designs, cross-sectional studies require low resource with less complexity, which makes them a preferred epidemiological study design for a low-resource study setting [96]. Even if a temporal sequence is difficult to establish between exposure and outcome in cross-sectional studies, scholars indicate that temporality is possible if the exposure undoubtedly precedes the outcome and cannot change over time [96,97]. These exposure factors included some demographic variables such as sex and ethnicity [96,97]. In general, the literature suggested the use of a retrospective, cross-sectional population survey design to study the occurrence of AGI in low-and-middle-income settings.

Incidence of AGI

Since population-level AGI studies were limited in African LMICs, I reviewed studies from countries of comparable population characteristics. Based on three studies in Asian LMICs (China), the yearly AGI incidence rate estimates ranged from 0.56 to 1.16 episodes per person-year [84,86,90]; whereas, two studies in Latin American LMICs (Argentina and Chile) reported yearly incidence rate estimates ranged from 0.46 to 0.97 episodes per person-year [85,98].

In the Caribbean countries, studies from Saint Lucia, Trinidad and Tobago, Jamaica, and Barbados estimated yearly AGI incidence rate of less than one episode per person-year (range: 0.5 – 0.67 episode per person-years) [23,24,82,92], while studies from Grenada, Dominica, and Guyana showed a yearly AGI incidence rate of greater than or equal to one episodes per person-year (range: 1 – 1.4 episode per person-year) [83,89,93].

Moreover, based on the study in Jamaica and Trinidad and Tobago, the yearly AGI incidence rate was higher among males than females (range of difference: 0.08 – 0.6 episode per person-year) [24,82]. Children less than five years of age had the highest yearly incidence rate of AGI (1.3 episodes per person-year) [82]. On the two studies found in African LMICs (i.e., Uganda and South Africa), the yearly incidence rates of AGI illness were 1.7 and 1.4 episodes per person-year, respectively [25,26].

Prevalence of AGI

Studies on the prevalence of AGI varied in the estimate range, the recall period used (i.e., one, two, or four weeks), and the study design used. According to available studies in Asian LMICs (including China, and India), the overall monthly prevalence of AGI ranged from 4.2% to 12% [81,84,86,90]. In South American LMICs, three studies in Argentina and Chile estimated an overall monthly prevalence of AGI ranged from 3.4% to 7.7% [85,98]. Uniquely, a study in Gaza Strip used a 2-day recall period, and the AGI prevalence for the specified recall period was 3.8% [87].

Based on a population level studies of the Caribbean countries, findings from Saint Lucia, Trinidad and Tobago, and Jamaica showed a slightly lower overall monthly prevalence of AGI ranging from 3.9% to 5.1% [24,82,92], whereas studies from Cuba, Grenada, Dominica, Guyana, and Barbados showed higher overall monthly prevalence of AGI ranging from 7.7% to 10.7%, in

the four weeks prior to data collection [23,83,88,89,93]. On available studies in African LMICs (i.e., Uganda and South Africa), the overall 2-weeks AGI prevalence were 6.17% and 5.3%, respectively [25,26].

Weighting accounts for better representation of estimates from samples of the population [99,100]. From studies in Asian LMICs (China), the age-, sex-, and residence-adjusted monthly AGI prevalence ranged from 1.8% to 7.7% [80,84,86,90]. In Chile, the age-adjusted monthly AGI prevalence was slightly higher: 9.2% [98]. From studies in Saint Lucia, Trinidad and Tobago, Dominica, and Guyana, the age- and sex-adjusted monthly AGI prevalence ranged from 4.5% to 9.9% and 3.8% to 8.4%, respectively [82,83,89,92]. Studies in the Caribbean countries also indicated that there was no significant difference between the weighted and unweighted prevalence [24,82,83,89].

Overall, the highest AGI prevalence was reported in Asian LMIC (i.e., south India) and the lowest in South American LMIC (i.e., Argentina). In Africa, based on available studies which used a 2-week recall, the prevalence estimates were within a range of studies done in Asian and South American LMICs and the Caribbean countries. The prevalence appears not to vary/or indifferently vary with the recall period chosen. Weighting seems to make a slight change on the estimates.

Severity and Secondary Symptoms of AGI

Because many things can cause loose stool, including non-infectious causes, studies often use the number of loose stools per day to define whether the respondent can be considered to have AGI [101]. In Asian LMICs, studies in China showed the maximum frequency of stool ranged from 4 to 4.7 times per 24 hours [84,90]. On a study in Chile, on the worst day, the maximum number of loose stools was 4.4 per 24 hours [98]. Studies from five Caribbean countries (i.e.,

Cuba, Saint Lucia, Grenada, Dominica, Guyana, and Barbados) indicated that the average maximum number of loose stools ranged from 4 to 5 per 24 hours [23,83,88,89,92,93].

In most cases, people with AGI have accompanying secondary symptoms [76,102]. Studies in Argentina and Chile reported headache (23% - 35%), fever (10% - 13%), and muscle pain (18%-23%) as secondary symptoms of AGI [85,98]. Respiratory symptoms were less common secondary symptoms of AGI (8.8% - 14.13%) in China, Hong Kong, and Chile [80,84,98]. In line with this, bloody diarrhea was less common (2.7% - 3.8%) in China, Hong Kong, and Chile; and slightly higher (16%) in Argentina [80,85,90,98].

Abdominal pain (range: 56.1% - 83.7%), headache (range: 23% - 42%), and nausea (range: 21% - 42.9%) were among the most common secondary symptoms experienced by individuals with AGI in studies from eight Caribbean countries (i.e., Cuba, Saint Lucia, Grenada, Trinidad and Tobago, Dominica, Guyana, Jamaica, and Barbados) [23,82,83,88,92,93]. Conversely, on studies in Dominica and Jamaica, abdominal pain and nausea were the least common, respectively [24,89].

Respiratory symptoms were less common in the Caribbean, which cough (range: 25% - 37.2%) and sneezing (range: 17.9% - 38.6%) were among the most common secondary symptoms experienced by individuals with AGI, based on studies from Dominica and Jamaica [24,89]. In the same way, runny nose (20.2%) was the common secondary symptom from a study in Dominica [89]. Blood in stool was also less common, and only the study from Cuba and Jamaica showed that a few individuals with AGI have blood in their stool [24,82,88].

Overall, secondary symptoms of AGI seem to vary from country to country, where symptoms most common in one location are found to be least common in another. This variation did not seem to link with location or study participants' characteristics, as abdominal pain and

nausea were the most common in some Caribbean countries and the least common in some Caribbean countries.

The duration of the AGI episode is the number of days the illness lasted (Lamberti et al., 2012). Based on a systematic review finding in LMICs, the mean duration for most episodes was 4.3 days (95% CI: 4.3 – 4.4) [103]. According to studies in few Asian LMICs (China and India), the average duration of AGI ranged from 1.8 to 2.5 days [81,84,86,90]. Studies in Argentina and Chile reported average duration of AGI ranged from 2.6 to 3.4 days [85,98]. The AGI duration slightly varied from the findings of studies in the Caribbean countries with a wide country-specific duration range (maximum country-specific range: 1 – 28 days). Studies in Trinidad and Tobago, Dominica, Cuba, Guyana, and Barbados showed average AGI duration of fewer than 3 days (range: 2 – 2.7 days); whereas, studies in Saint Lucia, Grenada, and Jamaica reported an average AGI greater than or equal to 3 days (range: 3 – 3.8 days) [23,24,82,83,88,89,92,93]. The study in rural Uganda (African LMICs) showed an average AGI duration of 4.48 days [25], and the one from South Africa reported a median duration of 2 days [26]. Overall, the average duration of AGI ranged from 2 to 4 days. Except for one study in rural Uganda, all studies from the LMICs reported an average illness duration less than or equal to 3.

Health Care Seeking for AGI

A significant portion of the population do not visit health facilities to receive health care for AGI [104]. Moreover, among the people who visit the health facilities, a substantial number of people do not get asked for a stool sample, and even if requested, there are individuals who fail to provide a sample and samples that are not submitted to the laboratory. Lastly, some laboratory diagnostics are not recorded, which subsequently results in underreporting of the actual laboratory-confirmed AGI illness burden. Thus, estimating the underreporting factors of the AGI cases

captured by the existing surveillance system helps to accurately determine the AGI burden in a country [56,57,104–107].

Epidemiological surveillance of AGI can capture the AGI burden on the segment of the community who seek health care [105,106]. The design of an intervention strategy to prevent or reduce the AGI burden requires an estimation of the AGI occurrences from the epidemiological surveillance reporting system within health care; however, the accuracy of such information highly depends on the health-seeking behaviour of the population [106]. In this regard, studies in high-income countries and few LMICs demonstrate the under-ascertainment of AGI occurrence in the surveillance system and the underreporting of the AGI by the laboratories within the health care system [23,56–58,82,83,89,92,93,104–106]. Estimation of the under-ascertainment and underreporting rates uses data from population surveys to determine the proportion who seek health care, the proportion who are requested to submit a stool sample to the laboratory, the proportion who submitted the samples, and the proportion who tested positive.

On AGI-related studies in China and Hong Kong, between 38.4% to 48.8% of the people with AGI sought medical care, and between 2% to 39.2% of those who sought care submitted stool samples [80,86,90]. In contrast, one study in China reported a higher (73.8% and 50.5%) proportion seeking care and providing stool samples, respectively [84]. In AGI studies in Argentina and Chile, about 21.2% to 26% of people with AGI sought medical care, and out of this, 1.93% to 11% submitted a stool sample to the laboratory [85,98]. Less than half of the individuals with AGI sought care in the Caribbean. For instance, according to studies from Saint Lucia, Trinidad and Tobago, Cuba, Guyana, and Dominica, among the people with AGI, less than one-fourth sought medical care (range: 16.7% - 24.7%) [82,83,88,89,92]. A slightly higher proportion

of people with AGI sought medical care on studies in Grenada, Jamaica, and Barbados, with a range from 31% to 36% [23,24,93]. Overall, of the people with AGI on studies in LMICs, less than half sought health care, with maximum and minimum proportion reported in Asian LMICs and the Caribbean, respectively.

Seasonality of AGI

As opposed to the individual-level determinants of diarrheal illnesses, ecological factors including weather, drinking water source (which are for use in cleaning or processing food), and agricultural and land use activities, can play a role in stimulating the seasonality of AGI [108]. The seasonal differences in temperature and rainfall patterns can contribute to water source contamination and agricultural land contamination [108]. The related flooding can nurture the growth of foodborne and diarrheal pathogens, on top of capacitating the sewage system, which can lead to contamination of the food supply [109]. Moreover, hot and humid weather facilitates the proliferation of pathogens in food and water and serves as a breeding season for the mechanical vectors of pathogens, e.g., flies, thereby influencing the occurrence of AGI in a community [110].

Thus, the occurrence of AGI varies according to the time of the year, categorized into seasons of a year [108,109,111]. A statistically significant difference in AGI prevalence was observed with seasonal variation on two studies in China, where the odds of AGI were 2.51 and 1.9 times higher in summer than winter and autumn, respectively [86,90]. On another study in China, the highest AGI prevalence (10.8%) occur in summer, but the difference was statistically insignificant [84]. A study on AGI in Barbados and Cuba showed that monthly AGI prevalence is higher (statistically significant) during the predefined high or rainy season [23,88]; in particular, in Barbados the odds of AGI were 2.2 times higher in the higher season than the lower season [23]. However, findings from studies in Grenada and Dominica indicated the statistically insignificant

difference (range: 0.2 – 0.9) of monthly prevalence in the predefined high and low season of diarrheal illness occurrence [89,93]. Overall, the occurrence of AGI does not seem to show a consistent variation across seasons of a year on studies in Asian and South American LMICs and the Caribbean.

Demographic Determinants of AGI

Demographic determinants are individual characteristics that can influence the occurrence of AGI [52,53,55].

Gender

Studies usually present sex-specific prevalence rates of illness, as a demographic variable assessed with health outcomes in most public health research undertakings [87,112]. Most studies reviewed here does not differentiate the influence between sex (i.e., biological factors) and gender (i.e., behavior, lifestyle, and life experience factors) on the occurrence of AGI [113]. Some findings indicated that AGI occurrence is higher among females than males, especially during the higher susceptibility period of pregnancy [51,114]. The situation aggravate due to pregnancy-enhanced cravings and the possible consumption of unsafe foods [114]. According to Anteneh and colleagues (2017), in young children, the higher occurrence of AGI in boys compared to girls could be due to the higher possibility of wandering off into unsanitary compounds than girls. There was also a study that reported males as having a higher prevalence of AGI than females in the general population, which was explained by the outside eating habit of males [23].

This distinction was further illustrated in studies, as presented hereafter in this section. According to two studies in China, the odds of having an episode of AGI were 1.19 and 1.43 times higher in females than males [86,90]. The AGI prevalence was also slightly higher among females (8.1%) than males (6.5%) on another study in Hong Kong, though this was not statistically

significant [80]. Similarly, on a study in Dominica, a statistically significantly higher AGI prevalence was observed among females, and the odds of having AGI were 1.6 times higher in females than males [89]. Studies in Saint Lucia, Guyana, and Grenada, also indicated a higher AGI prevalence in female than males (range of difference: 0.7 – 1.2), though this was not statistically insignificant [83,92,93]. The same held true for the study in Uganda, where females had a higher prevalence of AGI than males [25]. On other studies in China and India, the occurrence of AGI did not vary between males and females [81,84,86]. In contrast, males had 1.2 times higher odds of AGI than females on a study in Cuba (Aguiar Prieto et al., 2009). Correspondingly, AGI prevalence was higher (statistically insignificant) among males (range of difference: 0.6 – 1.11) on studies in Trinidad and Tobago and Barbados [23,82]. These variabilities of AGI distribution between females and males across studies in different countries might be due to an underlying cultural or population characteristics, on top of the natural susceptibility difference [51], which may require further investigation through qualitative studies and quantitatively by doing multivariable analysis.

Age

Findings showed a discrepancy in the age distribution of AGI. Barkley and colleagues pointed out that the developing immune system in young children put them at risk for AGI. The condition exacerbates if there is a decline in the provision of maternally acquired antibodies, the introduction of unhygienic weaning foods, and the risk of hand contamination during the crawling age of children, especially in rural areas [110]. According to Barkley and colleagues, a weakening of the immune system and carrying the pathogens in the intestine for prolonged periods put older individuals at risk for AGI. The weakening of the immune system can result from eating habits that reduce stomach acid and the use of antibiotics that destroy the healthy enteric flora [51].

This is exemplified in two studies in China that found that children aged less than five years had the highest prevalence compared to other age groups, and the odds of AGI were 1.89 and 2.82 times higher in children under 5 years than in individuals aged 45 to 64 years [84,90]. Likewise, in Malaysia, under-five children have 1.44 times higher odds of having AGI than children aged five to nine years [94]. Studies in Argentina and Chile also demonstrated that children under five had the highest prevalence and higher odds (2.98 and 3.25, respectively) of AGI compared to individuals aged 20 to 59 years [85,98]. On a study in rural Uganda, children, less than three years had 4.83 times higher odds of AGI than individuals aged 35 years or more [25]. In Caribbean countries, on studies in Grenada, Trinidad and Tobago, and Barbados, children under five years had a significantly higher prevalence of AGI than other age groups [23,82,93]. However, even though the prevalence of AGI was the highest among children aged less than 5 years, age was found to be statistically unassociated with AGI prevalence, on studies in Saint Lucia, Dominica, and Guyana [83,89,92]. In contrast, individuals aged 20 to 29 years showed the highest prevalence (6.7%), in a study from Malaysia, where the authors explained that this unique finding could be due to lifestyle and eating habits of young adults [94].

The lowest prevalence of AGI (3.4% - 6.6%) was seen among respondents aged greater than or equal to 60 or 65 years in studies from China, Hong Kong, Malaysia, and Chile [80,86,94,98]. In contrast, two studies in China reported that the lowest AGI prevalence was observed among individuals aged 5 to 14 years (2.9%) and 45 to 64 years (3.6%) [84,90]. In Trinidad and Tobago, Barbados, and Grenada, the lowest monthly AGI prevalence (range: 7% - 10.9%) was among individuals aged 45 years or more [23,82,93]; equally important, in Dominica and Saint Lucia the lowest prevalence (range: 2.6% - 7%) was among individuals aged 45 to 64 years [89,92]; whereas, in Jamaica, the lowest monthly prevalence (2.1%) was observed among

individuals aged 25 to 44 years [24]. In contrast, in Guyana, the lowest monthly AGI prevalence (6.5%) was recorded among individuals aged 15 to 24 years [83].

These diverse findings of the age distribution of AGI across different countries indicate that consideration of other population and cultural characteristics would help in further explaining the difference, in addition to the inherent susceptibility with age [51]. In summary, the highest prevalence of AGI was observed in children less than five years across studies in multiple LMICs. The lowest prevalence estimates of AGI were seen in age groups ranging from 45 to 65 years, with some exceptions.

Urban/ Rural Status

Studies point out that the AGI prevalence varies based on the location of residence (i.e., urban and rural status). Anteneh and colleagues indicated that a higher occurrence of AGI observed in rural areas could result due to factors such as low access to safe and adequate water supply and lack of awareness of hygienic and disease prevention practices. Some findings also showed that the occurrence is higher in urban population, which could be due to overcrowding in the urban slums that increase contacts to facilitate the spread of diarrheal infections [115,116]. Studies applied country-specific regulations on the statistical classification of urban and rural areas [84,90].

By way of illustration, studies in China and Malaysia showed a higher AGI in rural population than urban residents [90,94]. Whereas, in another study in China, a higher prevalence of AGI was seen among urban dwellers [84].

Household Income/Wealth

According to findings in the literature, household wealth status influences the occurrence of AGI occurrence. Some studies pointed out that individuals from a household of low wealth

status have a different health care access, health habit, eating pattern/ habit, and awareness of hygienic practices than individuals from a wealthier household, which in turn affects the susceptibility to AGI [90,117]. In a more general sense, the variation in AGI occurrence across different household income levels can be due to differential access to health care resources and different lifestyle behaviors [94,117].

For example, household income was statistically associated with AGI prevalence on a finding from a study in China, where people in households with higher household income had a higher odds of AGI [84]. Likewise, in Barbados, individuals with high income had two times increase in odds of developing the AGI than low-income individuals [23]. The possible explanation for the higher odds of disease among wealthier households can be a reporting bias, where households with higher income are more likely to perceive symptoms and pay more attention to hygienic practices, and they could tend to travel or eat out which could expose those individuals to acquire AGI [84]. Age and wealth have an interaction effect on the AGI prevalence, where children, adolescents, or seniors with higher wealth have higher odds of AGI illness. Here, as the investigators determined wealth by household assets, the more the households have assets, the more crowded the household gets, thereby facilitating person-to-person contact and increasing the probability of spread of infection [25].

Occupational Status

Concerning occupational status, Miech and Hauser, on their paper that focused on health outcomes in general, take issue with the contention that information on occupation might not be necessary if the educational status is adequately measured to assess the influence of socioeconomic factors on health outcomes, even if these two variables are distinct measures of socioeconomic status [118]. However, some studies found occupational status as a standalone demographic

determinant of AGI occurrence, for example a study conducted in Chile and Cuba, where AGI prevalence was statistically associated with occupation status, with a varying definition of the variable [88,98]. Based on the study in Cuba, the odds of having AGI were 1.4 and 1.8 times higher for those participants whose occupation was in services and administration, respectively, than being a housewife [88]. According to the study in Chile, the odds of having AGI were 1.42 times higher (marginally significant) for students than participants whose occupation was housewives [98]. These variations in the influence of different occupation on AGI occurrence could be due to the difference in the related economic activities in each country and the consequent perception of symptoms to report the disease [84,119].

Household Size

Studies indicate that household size can influence the occurrence of infectious diseases [53,120]. According to House and Keeling, the higher the number of individuals in the household, the more the probability for a household member to acquire and transmit the infection through contact [120]. In the same way, some studies found an association between household size and AGI. For example, individuals living with a median number of five or more people had a 2.1 times increase in odds of developing AGI, as per the finding from a study in Saint Lucia [92]. Similarly, on studies in China, individuals living with 3 or more members had a higher prevalence of AGI than those living with less than 3 members [84,90].

Other Risk Factor: Having Sick Individual(s) in the Household

According to studies on AGI, the presence of someone sick in the household can be a risk factor in acquiring AGI, as transmission of AGI pathogens can occur through a spread by person-to-person transmission [121,122]. Some studies also indicated that person-to-person transmission can get worsened by an infected food handler, which can lead to an outbreak in an institutional

setting [121,123]. Community-based case-control studies are a credible source of information about risk factors of AGI such as household member had AGI; however, as per my review of literature, such population-level studies are limited.

Based on the findings from population surveys in China, and countries in the Caribbean (Saint Lucia, Cuba, Trinidad and Tobago, and Barbados), between 1.47% to 23% of those with AGI reported that they had someone in their household sick with the same disease within the same four weeks' time before the data collection [23,82,88,90,92]. These findings can indicate that the presence of a sick individual(s) in the household could facilitate the spread of AGI by person to person transmission [121].

Summary of Literature Review

Estimates of the burden of AGI (including diarrheal illnesses, and often focused on foodborne illnesses) at the global, continental/regional, and sub-regional levels are available, as described above. The magnitude is similar to other major infectious diseases like HIV/AIDS, malaria and TB, and while AGI occurs globally, the greatest burden appears to be in Africa. However, in Africa, aggregate-level estimates cannot be efficiently inferable to specific countries, as the measures relied on assumptions, imputations, and are dependent on data availability and quality. Specifically, the literature implicated the necessity of country-based accurate estimates thereby enabling countries to make an evidence-based decision to reduce or prevent AGI.

The literature review showed that epidemiological studies of AGI in African LMICs are lacking. Globally, a few LMICs had population-based estimates of the burden of AGI, and these were almost exclusively conducted in LMICs outside Africa. In Africa, only two studies were available: one in the rural population of Uganda and one in urban settings of South Africa [25,26]. Moreover, studies of children in Africa mostly used two-week prevalence estimates, including the

studies in Uganda and South Africa, which limits the comparison of findings to studies globally, as it limits the consistency to case definitions identified in the literature which used four-week recall period. Other related studies in Africa and most LMICs in general focus on children under five years of age, including the DHS. Thus, there is a knowledge gap in the literature concerning the population-based estimate of epidemiology of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania.

Ultimately, to address this gap, the literature implied the use of a population-based cross-sectional survey methodological framework to collect retrospective self-reported data on the occurrence of AGI. Most of the studies in the high-income countries and almost all the studies found in the LMICs employed the population-based cross-sectional survey design. Accordingly, considering what previous studies have done, studies in African LMICs should use the population-based retrospective self-reported survey design to estimate the AGI occurrence. Population-based studies in African LMICs are critical not only to estimate the magnitude of AGI, but also to measure the under-ascertainment factors of the AGI reported in the existing surveillance system, and to measure the underreporting factor of the laboratory confirmed AGI in the respective African LMICs.

Moreover, studies in most high-income countries and a few LMICs identified demographic determinants of AGI. Available finding concerning demographic determinants: females have a higher risk of developing AGI than males, according to some studies, and vice versa in others; children aged fivers or below have a higher risk for AGI than other age groups; people in households with higher household income have a higher risk for AGI than those with lower household income; being a housewife have a lower risk for AGI than being a worker or a student; the higher the number of people sleeping per room (≥5 or ≥3) in a household the higher the risk

for AGI. However, there were some variations identified across studies. The disparity observed among these studies implied the need for country-based identification of demographic determinants of AGI, based on data from a population-based study; consequently, to enable the design of intervention strategies to reduce the AGI burden.

To conclude, in African LMICs, country-specific estimates on the epidemiology of AGI are necessary but scarce, and country-specific identification of demographic determinants are suggested. Therefore, studies on the epidemiology of AGI in African LMICs are critical and urgent.

Foodborne Disease Epidemiology, Surveillance and Control in African LMICs: The FOCAL Project

This thesis research was part of a multi-study research project co-funded by the Bill and Melinda Gates Foundation and the Foreign, Commonwealth & Development Office (FCDO) of the United Kingdom Government and led by the Technical University of Denmark (DTU; PI Dr. Hald), that aims to link public health surveillance data with pathogen occurrence data from food, animals and the environment, to providing the best evidence of the health impact of, and the relative contribution of different sources for, foodborne infections in African low-middle-income countries (LMICs). The FOCAL (Foodborne Disease Epidemiology, Surveillance and Control in African LMICs) project involves different studies, including a population survey to estimate the incidence and under-reporting of diarrheal illnesses in the four countries (namely: Ethiopia, Mozambique, Nigeria, and Tanzania) [124].

Upon the grant call for food safety research in African LMICs, partners from the FOCAL study countries came to work together through a pre-existing network via the initiative taken by the PI from DTU. The WHO categorized the African countries into two sub-regions considering

child and adult mortality. Three of the study countries (Ethiopia, Mozambique, and Tanzania) are from one of the WHO's sub-regions (AFR E), while one country (Nigeria) is from the other WHO's sub-region (AFR D) [3,4]. According to the WHO Foodborne Disease Burden Epidemiology Reference Group, data from these countries in the sub-regions were lacking, majorly in the former sub-region (AFR-E) [3,4].

I participated in developing the grant proposal, together with my supervisor, Dr. Majowicz. Once funded, I led the population survey that aimed to estimate the epidemiology of AGI in four African LMICs. I contributed to the development of the overall protocol by leading the sections concerning the population survey, and I developed the survey tool, coordinated the survey (in-person in one country and virtually in all) implementation, and performed data manipulation and analysis. To accomplish this, I actively engaged and collaborated with FOCAL partners Tesfaye Gobena (Haramaya University), Custodia Macuamule (Eduardo Mondlane University), Olanrewaju E. Fayemi (Mountain Top University), Christianah I. Ayolabi (Mountain Top University, University of Lagos), Blandina T. Mmbaga (Kilimanjaro Clinical Research Institute, Kilimanjaro Christian Medical University College), Kate M. Thomas (Kilimanjaro Clinical Research Institute, University of Otago), Warren Dodd (University of Waterloo), Sara M. Pires (Technical University of Denmark), Shannon E. Majowicz (University of Waterloo), and Tine Hald (Technical University of Denmark). In summary, I led the research activities of the population survey (under the supervision of Dr. Majowicz).

Impacts of COVID-19 on Planned Objectives

Due to the COVID-19 pandemic, data collection needed to measure the under-ascertainment of the AGI was impossible, but the pandemic provided the opportunity to work on COVID-19 instead. In this thesis, since this research was interrupted by the COVID-19 pandemic,

instead of measuring underreporting in AGI, a secondary aim was added to explore application of methods typically used to adjust for under-reporting of foodborne infections [56–58] to COVID-19.

1.3 Study Rationale and Objectives

Accurate estimates of the epidemiology of AGI, including the incidence, prevalence, determinants, and potential underreporting estimates, are critical to making evidence-based intervention decisions and for proper resource allocation in a country. Since resources are scarce and health problems are proliferating, prioritizing and accordingly allocating resources are unavoidable steps in public health programs and planning. Unless the epidemiology of AGI is accurately estimated, the underestimation of the disease burden on the community remains a possibility. Accurately determining the incidence and prevalence of AGI is essential to design targeted strategies to prevent or reduce disease burden. Information on demographic determinants of AGI also informs the design of interventions. In this regard, knowledge about AGI is scarce in Ethiopia, Mozambique, Nigeria, and Tanzania. Moreover, as the research to generate this type of knowledge is usually collaborative, although with the process mostly being undertaken behind the scenes, understanding the collaborative experience would fill the knowledge gap about such research processes in the African setting and be beneficial to similar studies in the future.

Therefore, the overall purpose of this thesis was to describe the epidemiology of AGI at the population level in Ethiopia, Mozambique, Nigeria, and Tanzania, and the collaborative process used to do so. Since this thesis was interrupted by the COVID-19 pandemic, a secondary aim was to explore application of methods typically used to adjust for under-reporting of foodborne infections [56–58] to COVID-19. The specific objectives of this thesis were to:

1. Describe the epidemiology of AGI in the general population in Ethiopia, Mozambique, Nigeria, and Tanzania, specifically to estimate the incidence, prevalence, and duration of AGI and identify demographic determinants (Chapter 2);

2. Self-evaluate the multi-national collaborative process used to achieve the first objective (Chapter 3);
3. Estimate the under-ascertainment multipliers for each step in the reporting chain for COVID-19 for an example setting with available data (Toronto, Canada) (Chapter 4).

These objectives were addressed via research described in three manuscripts prepared for peer-reviewed publication.

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Chapter 2

The epidemiology of acute gastrointestinal illness in Ethiopia, Mozambique, Nigeria, and Tanzania: a population survey

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Referencing and other formatting (e.g., British spelling such as 'diarrhoea') appears as per journal standards.

Summary

Gastrointestinal infections transmitted by food are a global concern and most severe in African low-and-middle-income countries (LMICs), though, in these countries, accurate data on acute gastrointestinal illness (AGI) are lacking. This study aimed to describe the epidemiology of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania. A population survey was conducted in one urban and one rural site in each of Ethiopia, Mozambique, Nigeria, and Tanzania, from October 01, 2020, to September 30, 2021, using both web-based and face-to-face survey tools (n=4500). Other similar surveys in high-income countries were adopted to develop the survey tool, and an internationally suggested case definition of AGI was used. The incidence of AGI (0.5 episodes per person-years) and the 4-week prevalence of 3.8% (95% CI: 3.2, 4.3) was comparable or lower than those from the other LMICs. The duration (4 days) appeared slightly longer or similar to other LMICs. Although age was a significant risk factor, gender was not. In conclusion, this study identified that in Ethiopia, Mozambique, Nigeria, and Tanzania, AGI appears to pose a considerable incidence that suggests regular surveillance and intervention are needed.

Introduction

Gastrointestinal infections transmitted by food are a global concern [1], and Low and Middle-Income Countries (LMICs) bear the highest-burden [2,3]. These infections are severe in Africa, illustrated by the 1 in 10 children and 1 in 13 all-ages deaths caused by diarrhoea [2,4]. Aggregate-level estimates indicate that the diarrhoeal disease burden in Africa (LMICs) is higher than the burden estimate of malaria, preterm birth complication, and tuberculosis and comparable to HIV/AIDS [4,5].

However, in African LMICs, accurate data on acute gastrointestinal infections (AGIs) are lacking. Many countries have done population surveys to study the epidemiology of acute gastrointestinal illnesses [6–13], but only two studies were found at the general population level in Africa: one study in an indigenous community in Uganda [14] and another in an urban setting in South Africa [15]. Except for the World Health Organization (WHO)'s aggregate-level estimates [16], crude reports of annual diarrhoeal cases and rare population studies [17–19], accurate estimates of incidence, prevalence, and duration of AGI are lacking.

Studies, including the Demographic and Health Survey (DHS), report [20–23] that focus on diarrhoea in children under five and use a two-week recall period found the prevalence of diarrhoeal illnesses of 6 to 22% [24–32]. However, as most epidemiology of diarrhoea studies are centred on under-five children, there is a knowledge gap about diarrhoea in those above five years old, but also about AGI more widely at all ages in African LMIC. Moreover, having incomparable (i.e., 2-week versus 4-week recall; varying use of case definition) national incidence/prevalence estimates: limit the nation's ability to compare its achievements on the control of AGI on an international basis; make it difficult to contribute to international research collaborations; could affect the country when international-level policies are made [33–37]. This study aimed to describe

the epidemiology of AGI at the population level in Ethiopia, Mozambique, Nigeria, and Tanzania, specifically to estimate the incidence, prevalence and duration of AGI and identify demographic determinants.

Methods

Study Design

A retrospective cross-sectional population survey, collecting self-reported data on the occurrence of AGI, was conducted from 1 October 2020 to 30 September 2021 in Ethiopia, Mozambique, Nigeria, and Tanzania. The target population was the general population (i.e., all community members), and the study was conducted in one urban and one rural site in each country. Details of the study sites are given in Appendix B (Table B1).

The initial minimum target sample size of 372 for each site was calculated assuming a large population size, 10% estimated AGI prevalence, 3.1% allowable error, and 95% certainty [38]. From this minimum, the target sample size then varied by country, due to the distance it took to go to the study sites and move house to house, and the cost of enumerators' time (Appendix B, Table B1). Country-specific target sample size were adjusted, in one country (i.e., Mozambique), following the pilot (described below).

Respondents provided informed assent/consent, and those 18 years and older answered the survey for themselves. Parents provided consent for young children and answered the survey for them, and youth also provided assent in addition to parental consent and could choose to answer the survey themselves or have a parent answer; specific ages varied by country and are given in Table B1 in Appendix B.

This study was approved by nine research ethics boards in five countries (Appendix B, Table B1), including a University of Waterloo Research Ethics Committee (#40458).

The Survey Tool

The survey (Appendix C) was designed using standard questions from other AGI population surveys conducted in Canada, Denmark, Germany, Ireland, Italy, and New Zealand [6–10]. The survey predominantly used closed-ended questions with a list of predefined responses and a few semi-open-ended questions. The survey was developed in English and then translated into five other languages commonly spoken in each country (Appendix B, Table B1). Research team members reviewed survey drafts and provided inputs that helped to address the suitability of the survey to the local African contexts.

The survey collected information on: diarrhoea (defined as any loose stool or stool with abnormal liquidity) or vomiting in the four weeks prior to the survey date: the date the illnesses started; the number of days the illnesses lasted; age; gender; wealth index (measured by questions on housing conditions, water supply and sanitation conditions, and property/ material ownership) [39,40]; employment status of the main earner in the household; number of people sleeping per room; urban/rural status; country; and the date the survey was completed. The date the survey was completed was used to create the variable season, which followed each country's start and end date of the dry and wet seasons (defined in Table 2.1).

For those reporting diarrhoea or vomiting in the 4-week recall period, the survey also asked about: the symptoms; the most number of times they had loose stools or vomited on the worst day; the other symptoms they had; if they were sick on the day of data collection; other conditions that could have caused the diarrhoea or vomiting; if they sought care for medical advice or treatment of the symptoms; if they were admitted to hospital overnight for their illness; if they were asked for to provide stool samples for testing by a laboratory; if they provided the requested stool sample; the result of the stool sample (if known); whether they took any

medications for their symptoms; the type of medication they took; and the number of other people in their household who had diarrhoea or vomiting within the past 4 weeks. For respondents with more than one diarrhoea or vomiting episode in the four weeks before the survey, episodes separated by a seven-day gap were considered separate episodes (and those separated by six days or less to be part of the same episode).

The survey tool was pretested with a convenience sample in each of the four countries until no new changes were noted.

Data Collection

The survey was administered via face-to-face interviews with enumerators and a web survey. The study team decided to use these two methods since the prior plan of web survey only was found to be an inefficient approach due to the lack of access to the internet/technology and the varying literacy status in the chosen study communities. Both the face-to-face and web modes of administration used an online survey system (i.e., Qualtrics Insight Platform [41]).

In the face-to-face interviews, the enumerators were trained and carried out the survey using a tablet prepared for this purpose. Enumerators used simple random sampling to identify households, and then randomly selected a person (with the most recent birthdate or by lottery method) in the house. Household revisits or picking the following eligible individual were the actions taken when individuals were unavailable at the time of data collection. However, when the selected individual refused to participate, the data collectors moved to the next household.

In the web survey, the study community received an invitation to participate (Appendix B, Table B1). An anonymous web link was made available to people who chose to complete the survey online. The survey was promoted via health extension workers, local community gatherings, available social media (e.g., WhatsApp), flyers, and posters. Since respondents might

have chosen to complete the web survey more than once, questions about previous participation were included. Although every household member might complete the questionnaire in the web survey format, no attempt was made to link survey responses within households, as there was no such information collected. In countries that offered remuneration, respondents were only remunerated for the first time they completed the web survey. The web survey was set up to guide the respondents to follow along and provide consent/ assent according to the age of the respondent, as described above.

Although researchers in each study country started data collection in February/March 2020, data collection was paused on 26 March 2020, due to the COVID-19 pandemic and the related public health measures. Data collection resumed on 01 October 2020. Data collected in February/March 2020 and October 2020 were used as the survey pilot. Following analysis of the pilot data, no changes were required to the survey tool. The country-specific prevalence estimates from the pilot study were less than 10%, but the only change made was to the sample size estimate from Mozambique, which is set to 552 (Appendix B, Table B1). Because no substantive changes were made to the survey, the data collected for October 2020 was included as the first month of the one-year data collection.

Analysis

Data for all study communities were analysed in a single dataset, in SAS 9.4 (SAS Institute, Cary, NC), with incidence rates and proportions calculated using R version 4.0.2. Individuals with 'don't know/not sure' responses, those who refused to answer a question or who provided implausible responses (identified as nonsensical values using population level information in each country [20–23], e.g., 60 people sleeping per room, age of 170 years), were excluded from the analysis of that question.

AGI Case Definition

AGI was defined using a published standard case definition of ≥3 loose stools, or any vomiting, in 24 hours, excluding those: (a) with cancer of the bowel, irritable bowel syndrome, Crohn's disease, ulcerative colitis, cystic fibrosis, coeliac disease, or another chronic illness with symptoms of diarrhoea or vomiting; or (b) who report their symptoms were due to drugs, alcohol, or pregnancy) [42]. The DHS definition (diarrhoea during the two weeks preceding the survey - with the number of loose stools not specified - in children under five years of age) was also applied to enable comparison of this study to the DHS reports. Here, any diarrhoea (no matter the number of stools was in a 24 hour period) in the two weeks preceding the survey in children under five was used [20–23].

Incidence, Prevalence, and Duration

To ensure the representativeness of the survey data, a weighting variable – for age, gender, and urban/rural status – was created based on national census reports [43–46] in the study countries. Then, the sample weights were applied in the entire estimation and analysis.

AGI incidence rate and proportion and prevalence estimates were calculated using the formulae in Appendix D [47,48]. For respondents who reported having more than one episode, the most recent episode was the only one used when calculating incidence (i.e., individuals with more than one episode of AGI in the 4-week period were included in the numerator only once for the incidence calculation). To calculate the incidence, the numerator was the number of respondents with AGI during the 4-week recall. Since this group could include individuals ill during the 4-week recall period but whose symptoms started before the 4-week period, the incidence rate was adjusted to account for the likely proportion of episodes that started before the 4-week period. For this purpose, first, an assumption was made that AGI cases occurred evenly

throughout the 4-week period. Then, the average duration of illness was used to estimate the probable proportion of illnesses that began before the 4-week period. The incidence rate was adjusted by subtracting this proportion (see the Formulae in Appendix D) from the numerator and denominator of the incidence rate calculation [6].

The 4-week prevalence of AGI was calculated as the proportion of respondents with AGI in the 4-week recall period, regardless of the illness start date. A similar calculation was done to determine both a 2-week prevalence of AGI in all respondents, and a 2-week prevalence of diarrhoea among children under five years (i.e., the DHS definition). The point prevalence was calculated as the proportion of respondents with AGI on the day of the data collection. The mean and median duration of AGI illness were calculated using the duration as reported by respondents; here, those with symptoms still on-going during the date of data collection were not excluded.

Determinants of AGI

All demographic, temporal, and spatial distributions were summarized descriptively, using percentages per categories for categorial variables and mean, median, and range for continuous variables with the respective 95% confidence intervals. The null hypothesis of no association between presence of AGI (4-week recall) and demographic variables was tested using the χ^2 test at a significance level of 0.05.

The association between demographic factors and the presence of AGI in the previous four weeks was tested by fitting five multivariable logistic regression models: one overall and four country-specific models. A weight adjustment was not applied in this analysis since the purpose was to assess the odds of having AGI among determinant factors. Individual-level (age and gender), household-level (wealth index, employment status, and the number of people

sleeping in the household), and country-level (month, season, and urban/rural status) variables were tested. A two-way interaction effect of selected variables (age with each of gender, residence, wealth, employment status of main earner, method of data collection, and season; gender with each of residence, wealth, employment status of main earner, and season; residence with each of wealth, number of people sleeping per room, and season) on the odds of AGI was tested. All demographic variables were included in the final models regardless of their significance at 0.05 level [49].

The wealth index was assessed as a proxy for measuring wealth, following a standard approach in equity analysis [39,40]. Each wealth variable (household utilities, assets, fuel for cooking, and crowding) was recoded into two categories by grouping the response options to where they are more likely to be found: wealthier versus poorer households (Table B2 in Appendix B). The wealth index was then determined, based on these variables, via principal components analysis (PCA). The variables having frequencies between 5% and 95% were included in the PCA, as frequencies outside this range would not be helpful to differentiate individuals using the wealth index [50]. As assets could vary by worthiness/price between urban and rural areas, the wealth index for urban and rural settings was determined separately for each country and then merged for further analysis. The first component, obtained from the PCA, was used to categorize individuals into five approximate quintiles of wealth ranging from the lowest to highest quintile [50].

Results

A total of 4500 respondents completed the survey across all the study countries, and 29% were web survey respondents (Table 2.1). Overall, more females (61%) participated than males (p-value<0.0001), and demographic characteristics of respondents and the 4-week prevalence are shown in Table 2.1.

Incidence and Prevalence

Of the 4500 respondents, 4425 had complete information on variables that measured the monthly occurrence of diarrhoea or vomiting. Of the 4425, 360 (8.1%) had any diarrhoea or vomiting in the four weeks before the survey completion date, and of these 360, 166 (46.1%) met the definition for AGI. The annual incidence rates in all countries and overall were less than one episode of AGI per person-year, and the adjusted incidence proportion was less than one (Table 2.2). The annual incidence rate was similar in all countries except Ethiopia, where it was higher (Figure 2.1). The 4-week prevalence was 3.8% (95% CI: 3.2, 4.3) (Table 2.2). In all but Ethiopia, the point prevalence were below one percent (Table 2.2).

Of the 4330 respondents with complete information on variables that measured the occurrence of diarrhoea or vomiting in the past two weeks, 53 (1.2%) had AGI in the two weeks before the survey completion date. The 2 -week prevalence of diarrhoea among children under five was less than 10% except for Mozambique, where it was 21% (Table 2.2).

Severity and symptoms

More than 86% of the 166 people with AGI had diarrhoea (Table 2.3). On the worst day, the average maximum number of stools and vomiting episodes were four and three, respectively. The mean duration of AGI reported in the study countries ranged from three to five days. At least 30% of cases of AGI in all countries had more than one episode in the previous four weeks. Among all AGI cases, roughly a quarter of them had someone else in the household with AGI (ranging from 9% in Tanzania to 37% in Mozambique). In those with AGI, abdominal pain, stomach pain, fever, headache, and nausea were the most common additional symptoms reported in almost all the study countries (Table 2.3).

Health care seeking behavior

The proportion of AGI cases who sought care ranged from 37% (Mozambique) to 74% (Tanzania; Table 2.4). Of those who sought care, the proportion requested to submit a stool sample ranged from a minimum of 4.5% (Nigeria) to a maximum of 69% (Tanzania). The majority (>85%) submitted the requested submit stool. Less than half of those who submitted stool samples tested positive (10/29; 35%). About 62% or more of those with AGI in each country took medication for their symptoms. Those with AGI who sought care were more likely to also take medications for their symptoms in Ethiopia ($p<0.0001$), Mozambique ($p=0.0264$), Nigeria ($p<0.0001$), and Tanzania (all who sought care took medication) (Table 2.4).

Seasonal variation

The 4-week prevalence by study month is displayed in Figure 2.2 and shows no clear temporal pattern. AGI prevalence was not significantly different between wet and dry seasons (Table 2.1), even after accounting for other demographic factors at the country-level and overall (Table 2.5-2.9).

Demographic Determinants of AGI

Age was the only factor associated with having AGI in each of the four countries, with a higher odds in those 0-4 and 5-9 years of age, compared to those 25-69 age years (Table 2.5-2.9). Other significant factors within countries were the employment status of the household's main earner and wealth index, as follows. In Mozambique, individuals from a household with working or student main earners were 9.5 and 14.6 times more likely to have AGI than households with housewife main earners, respectively (Table 2.7). In Nigeria, individuals in a household with the fourth- and highest-level assets were four times more likely than those with second-and middle-level assets to have AGI (Table 2.8). When all countries were analyzed together: individuals

from rural sites were 1.5 times more likely than those from urban sites to have AGI; individuals in a household where the main earner was working were 2.1 times more likely than those in a household where the main earner was a housewife to develop AGI; and individuals who participated via the face-to-face survey were 1.8 times more likely than those who participated in the web survey to have AGI (Table 2.5). These results are adjusted for all other factors in the model.

Discussion

The purpose of this study was to describe the epidemiology of AGI at the population level in Ethiopia, Mozambique, Nigeria, and Tanzania, specifically to estimate the incidence, prevalence and duration of AGI and identify demographic determinants. The annual incidence rates of AGI reported in the four countries of this study (0.35 to 0.87 episodes per person-year) were comparable or slightly lower than that rates in Asian LMICs (China; range: 0.56 – 1.2 episode per person-years [51–53]; Latin American LMICs (Argentina and Chile; range 0.46 - 0.97 episode per person-year) [54,55]; and Caribbean countries (Saint Lucia, Trinidad and Tobago, and Barbados; range: 0.52 – 0.67 episode per person-year) [12,56,57]. The incidence rates from other studies in the Caribbean (Grenada, Dominica, and Guyana) [58–60] and two studies in African LMICs (Uganda and South Africa) [14,15] are incomparable to the estimates from this study as they had either applied a different case definition or recall period. Likewise, the 4-week prevalence of AGI in the four countries in this study (range: 2.7% to 6.4%) are comparable or slightly lower than estimates in studies from Asian LMIC (China; range: 4.2% – 8.5%) [51–53]; Latin American LMICs (Argentina and Chile; range 3.4% – 7.7%) [54,55]; and Caribbean countries (Saint Lucia, Trinidad and Tobago, and Barbados; range: 3.9% – 5.1%) [12,56,57]. The comparable or lower AGI incidence and prevalence estimates from this study could be due to the extensive promotion of

handwashing practices, including the use of alcohol or sanitizer to clean hands, during the study period that aimed to contain the COVID-19 pandemic [61]. The improved handwashing practice had the potential to not only impact COVID-19 but also influence the incidence of AGI [62]. Regardless, the comparability of this study's incidence rates still indicates the significant health burden posed by AGI.

Upon applying the DHS case definition (i.e., any diarrhoea in the two weeks preceding the survey in children under five) in this study, the prevalence estimate of one country (i.e., Ethiopia; 9%) was the only one in a range of the country's previously-published DHS estimate (12%) [20]. The other DHS-defined prevalence estimates from this study for children under five years are at least 9% either higher (Mozambique: 21%) or lower (Nigeria: 1%; Tanzania: 2%) than the estimates from the actual DHS reports (Mozambique: 11%; Nigeria: 10%; Tanzania: 12%) [21–23]. The lower prevalence estimates in this study (in Ethiopia, Nigeria, and Tanzania) compared to the DHS ones could be due to the improved hand hygiene of children or their caretakers to prevent COVID-19, as that could potentially influence the occurrence of AGI [63]. The higher estimate in Mozambique could be due to sampling error, as demonstrated by the slight reduction to 17% upon weight adjustment for age, gender, and urban/rural status.

The severity of AGI, when using mean duration of illness, in the study countries of this study (range: 3 – 5 days) is comparable or slightly greater than that reported in an Asian LMIC (China; range: 2 – 3days) [51–53]; Latin American LMICs (Argentina and Chile; range: 2 – 3 days) [54,55]; and the Caribbean countries (Saint Lucia, Trinidad and Tobago, and Barbados; range: 2 – 4 days) [12,56,57]. When using the average maximum number of loose stools and vomiting episodes in 24 hours in the study countries of this study, the severity of AGI is comparable to that reported in an Asian LMIC (China) [51,53], a Latin American LMIC (Chile)

[54], and Caribbean countries (Saint Lucia and Barbados) [12,56]. The comparable or slightly greater severity of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania observed here could be due to the differences in the type of prevalent pathogens, in immunity levels of population sub-groups, in access to health care/medication, and indirect factors such as living condition, hygiene, and eating habit/nutrition. As AGI is more severe in African LMICs than others, the consequence of AGI could be more devastating in these populations than others [2,4].

Except in one country (i.e., Nigeria), more than half of AGI cases in the study countries sought medical care, which is higher than those reported in China, Argentina, Chile, Saint Lucia, Trinidad and Tobago, and Barbados [12,52–57], besides one another study with comparable estimates in China [51]. The higher proportion of AGI cases who sought medical care in this study could be explained by the information distributed – by worldwide researchers or the public health officials of the respective countries – to the public that linked AGI with COVID-19 symptoms during the pandemic [64]. Consequently, individuals with such information could seek more care for their AGI symptoms than they would have prior to the pandemic.

In this study, the occurrence of AGI did not show a variation between wet and dry seasons (as defined by each study country) either in the bivariable or multivariable analysis. The lack of association is in contrast with some studies in LMICs (China, Barbados, and Cuba) [12,52,53,65], while consistent with other studies in China, Grenada, and Dominica [51,59,60]. This lack of association could be due to the small number of AGI cases (n=166) in the four study countries in a year, which could be attributed to the improved hand hygiene to prevent COVID-19, and sample size.

Consistent with studies in other LMICs [12,51,53–55,57], children aged less than five years had the highest prevalence of AGI compared to those aged 25 to 69 years in the study countries of

this study, adjusting for other demographic factors in the multivariable logistic regression models. The higher rates in children than adults confirmed that children, especially in LMICs, are at a higher risk of developing AGI, which could be attributed to the developing immune system in young children [66]. The condition can be debilitating when children did not get maternally acquired antibodies and hygienic weaning foods and were exposed to hand contamination during their crawling age, especially in rural areas [67].

Consistent with a study in China [51], those who lived in the rural setting were 1.5 times more likely to experience AGI than those who lived in the urban settings, which is in contrast with another study in China [53]. A higher AGI occurrence in the rural than the urban settings could be due to low access to safe and adequate water supply, and also low level of awareness of hygienic practices [68]. Also, individuals in a household with working or student main earners had a higher prevalence of AGI than those in a household where the main earner was a housewife. This association is consistent with studies in Cuba and Chile, even though the variable definition slightly varied [54,65]. AGI prevalence could vary across different occupations of the household's main earner due to the difference in the related economic activities and the consequent perception of symptoms to report the illness [53,69]. In one of the study countries (i.e., Nigeria), individuals in a household with the fourth- and highest-level assets were four times more likely to experience AGI than those with second-and middle-level assets, which is consistent with studies in China and Barbados [12,53]. The possible explanation for the higher odds of AGI among individuals in wealthier households could be a reporting bias, where individuals with higher income are more likely to perceive symptoms and pay more attention to hygienic practices. Lifestyle, where they could tend to travel or eat out, which could increase the risk for developing AGI, could be another explanation [53].

As described in other similar studies elsewhere [12,51,70,71], two limitations were identified in this study. First, the generalizability of the findings to the within-country population needs to be approached cautiously, given the multi-ethnicity or multi-cultural groups available in the countries. Nonetheless, given the possibility of a mixed aggregate of multiple ethnic populations in the selected areas, the weighting of sample estimates, using the available recent census data, likely improved the representativeness of the sample data. Second, biases such as recall bias, interviewer bias, and misclassification bias are expected in studies using self-reported case definitions. The activities that helped minimize such biases were enumerators' training, optimal data collection time, and an online survey with control logic to reduce mistyping.

In conclusion, this study provides the first estimates of the epidemiology of AGI at the population level using an internationally comparable case definition in African LMIC. The study reveals a significant incidence of AGI in the study communities in Ethiopia, Mozambique, Nigeria, and Tanzania, with higher rates in children under five years of age, those located in a rural setting, and those in a household with the main earner was working. The results demonstrate that the epidemiology of AGI in the four African LMICs of this study corresponds to those reported from studies in other LMICs. The information on demographic determinants of AGI would help to allocate resources for the control of AGI, and regular surveillance and ongoing epidemiological studies are needed to inform actions targeting the reduction of the incidence of AGI in African LMICs.

Table 2.1 Demographic characteristics of survey respondents and 4-week prevalence of acute gastrointestinal illness (AGI) in Ethiopia, Mozambique, Nigeria, and Tanzania (October 2020 – September 2021; n=4500) and bivariable associations between demographic variables and 4-week AGI prevalence; p-values less than 0.05 are in bold

Variable	**Overall**		**Ethiopia**		**Mozambique**		**Nigeria**		**Tanzania**	
	Number (%)	**Prevalence (95% CI*)**	**Number (%)**	**Prevalence (95% CI*)**	**Number (%)**	**Prevalence (95% CI*)**	**Number (%)**	**Prevalence (95% CI*)**	**Number (%)**	**Prevalence (95% CI*)**
Gender										
Male	1755 (39.1)	3.9 (3.6, 4.1)	174 (21.9)	8.7 (4.9, 12.6)	340 (36.6)	3.8 (2.0, 5.7)	626 (42.6)	3.0 (1.9, 4.1)	615 (47.6)	3.4 (2.2, 4.7)
Female	2731 (60.9)	3.7 (3.5, 3.9)	621 (78.1)	5.8 (4.1, 7.5)	588 (63.4)	4.3 (2.8, 5.7)	845 (57.4)	2.5 (1.6, 3.4)	677 (52.4)	2.7 (1.6, 3.7)
Total	4486 (100)	3.8 (3.6, 3.9)	795 (100)	6.4 (4.9, 8.0)	928 (100)	4.1 (3.0, 5.3)	1471 (100)	2.7 (2.0, 3.4)	1292 (100)	3.0 (2.2, 3.8)
P-value		0.7302		0.1683		0.7646		0.5523		0.4355
Age (years)										
0-4	509 (11.6)	9.4 (8.7, 10.2)	122 (15.5)	16.4 (10.4, 22.4)	24 (2.6)	12.5 (0.6, 24.4)	308 (21.3)	5.8 (3.7, 8.0)	55 (4.3)	12.7 (5.2, 20.3)
5-9	178	6.2	11	18.2	4	50	123	4.1	40	5

	(4.0)	(5.2, 7.2)	(1.4)	(0.0, 39.1)	(0.4)	(5.8, 94.2)	(8.5)	(1.1, 7.0)	(3.2)	(0.0, 10.8)
10-19	299 (6.8)	3.4 (2.8, 4.0)	28 (3.6)	7.4 (0.0, 16.5)	61 (6.7)	10.0 (3.2, 16.8)	128 (8.9)	0.8 (0.0, 2.1)	82 (6.5)	1.2 (0.0, 3.3)
20-24	577 (13.1)	5.2 (4.6, 5.7)	80 (10.2)	6.3 (1.4, 11.3)	106 (11.7)	6.6 (2.3, 10.9)	121 (8.4)	2.7 (0.2, 5.3)	270 (21.3)	5.3 (3.0, 7.6)
25-69	2674 (60.7)	2.1 (2.0, 2.3)	496 (63.1)	3.4 (2.0, 4.9)	685 (75.5)	2.3 (1.3, 3.4)	760 (52.6)	1.4 (0.7, 2.1)	733 (57.9)	1.8 (1.0, 2.6)
>70	167 (3.8)	4.2 (3.3, 5.1)	49 (6.2)	8.2 (1.1, 15.2)	27 (3.0)	11.1 (0.4, 21.8)	4 (0.3)	-0.0 (-0.0, 0.0)	87 (6.9)	0.0 (0.0, 0.0)
Total	4404 (100)	3.7 (3.6, 3.9)	786 (100)	6.4 (4.8, 8.0)	907 (100)	4.1 (2.9, 5.3)	1444 (100)	2.7 (2.0, 3.4)	1267 (100)	2.9 (2.1, 3.7)
P-value		**<0.0001**		**<0.0001**		**<0.0001**		**0.0018**		**<.0001**
Mean		31.1		33.1		37.0		23.4		34.3
Median		30.0		32.0		35.0		26.0		29.0
Wealth index quintile										
Lowest	857 (20.5)	4.1 (3.8, 4.5)	153 (19.8)	4.6 (1.5, 7.6)	176 (19.8)	5.1 (2.2, 8.0)	283 (21.9)	3.3 (1.5, 5.1)	245 (20.0)	4.1 (2.0, 6.3)
Second & Middle	1670 (40.0)	3.3 (3.0, 3.5)	314 (40.6)	6.1 (3.7, 8.5)	365 (41.1)	4.9 (2.9, 7.0)	499 (38.6)	1.0 (0.3, 1.8)	492 (40.1)	2.4 (1.3, 3.6)

Fourth	815 (19.5)	4.7 (4.3, 5.1)	152 (19.7)	9.9 (5.5, 14.2)	168 (18.9)	2.4 (0.3, 4.5)	252 (19.5)	4.5 (2.3, 6.7)	243 (19.8)	3.3 (1.4, 5.3)
Highest	838 (20.0)	4.2 (3.8, 4.6)	154 (19.9)	6.5 (2.9, 10.1)	178 (20.1)	3.4 (1.0, 5.8)	259 (20.0)	4.3 (2.2, 6.4)	247 (20.1)	3.3 (1.3, 5.2)
Total	4180 (100)	3.9 (3.7, 4.1)	773 (100)	6.6 (5.0, 8.2)	887 (100)	4.2 (3.0, 5.4)	1293 (100)	2.9 (2.1, 3.6)	1227 (100)	3.1 (2.3, 4.0)
P-value		0.3245		0.2864		0.4635		**0.0165**		0.6569
Residence										
Urban	2306 (51.2)	3.0 (2.8, 3.2)	411 (51.7)	6.1 (4.0, 8.2)	429 (46.2)	3.5 (1.9, 5.1)	722 (48.8)	1.5 (0.7, 2.3)	744 (57.5)	2.3 (1.4, 3.2)
Rural	2194 (48.8)	4.5 (4.3, 4.8)	384 (48.3)	6.8 (4.5, 9.1)	500 (53.8)	4.6 (2.9, 6.3)	759 (51.2)	3.7 (2.6, 4.8)	551 (42.5)	4.0 (2.6, 5.4)
Total	4500 (100)	3.8 (3.6, 3.9)	795 (100)	6.4 (4.9, 8.0)	929 (100)	4.1 (2.9, 5.3)	1481 (100)	2.7 (2.0, 3.4)	1288 (100)	3.0 (2.2, 3.8)
P-value		**0.0072**		0.6985		0.3978		**0.0113**		0.0720
Employment status of main earner in the household										
Working	3259 (73.6)	4.0 (3.8, 4.2)	556 (70.2)	7.2 (5.2, 9.2)	694 (75.5)	4.8 (3.3, 6.2)	1116 (76.2)	3.0 (2.1, 3.8)	893 (71.2)	2.8 (1.9, 3.8)
Retired	270	3.4	36	11.1	57	3.5	50	2.1	127	1.6

	(6.1)	(2.7, 4.0)	(4.5)	(1.7, 20.5)	(6.2)	(0.0, 7.8)	(3.4)	(0.0, 5.6)	(10.1)	(0.0, 3.4)
Student	410 (9.3)	3.4 (2.8, 3.9)	25 (3.2)	0.0 (0.0, 0.0)	30 (3.3)	6.7 (0.0, 14.7)	193 (13.2)	1.2 (0.0, 2.5)	162 (12.9)	5.6 (2.5, 8.6)
Housewife	438 (9.9)	2.3 (1.9, 2.7)	173 (21.8)	4.0 (1.4, 6.7)	116 (12.6)	0.9 (0.0, 2.4)	99 (6.8)	1.1 (0.0, 2.8)	50 (4.0)	2.1 (0.0, 5.6)
Disabled	44 (1.0)	4.5 (2.8, 6.3)	1 (0.1)	0.0 (0.0, 0.0)	17 (1.8)	0.0 (0.0, 0.0)	6 (0.4)	0.0 (0.0, 0.0)	20 (1.6)	10.0 (0.0, 21.3)
Others	10 (0.2)	10.0 (4.7, 15.3)	1 (0.1)	0.0 (0.0, 0.0)	5 (0.5)	0.0 (0.0, 0.0)	1 (0.1)	100.0 (-, -)	3 (0.2)	0.0 (0.0, 0.0)
Total	4431 (100)	3.8 (3.6, 3.9)	792 (100)	6.5 (4.9, 8.0)	919 (100)	4.1 (3.0, 5.3)	1465 (100)	2.6 (1.9, 3.3)	1265 (100)	3.1 (2.3, 4.0)
P-value		0.4753		0.3741		0.3786		**<0.0001**		0.1652
No. people sleeping per room										
≤ 3	3264 (75.7)	3.2 (3.0, 3.4)	258 (32.8)	5.0 (2.6, 7.5)	813 (90.3)	4.1 (2.8, 5.3)	1117 (77.6)	2.4 (1.7, 3.2)	1076 (90.9)	2.8 (2.0, 3.7)
> 3	1047 (24.3)	5.9 (5.4, 6.3)	529 (67.2)	7.2 (5.2, 9.2)	87 (9.7)	5.7 (1.3, 10.2)	323 (22.4)	3.8 (2.0, 5.5)	108 (9.1)	5.6 (1.8, 9.3)
Total	4311 (100)	3.8 (3.7, 4.0)	787 (100)	6.5 (4.9, 8.1)	900 (100)	4.2 (3.0, 5.4)	1440 (100)	2.7 (2.0, 3.5)	1184 (100)	3.1 (2.2, 3.9)

P-value		**<0.0001**		0.2462		0.4584		0.2119		0.1138
Mean, Median, (Range)		2.9, 2.0 (1 - 15)		4.7, 4.0 (1 - 15)		2.4, 2.0 (1 - 14)		2.7, 2.5 (1 - 9)		2.4, 2.0 (1 - 7)
Method of data collection										
Web-survey	1300 (28.9)	3.3 (3.0, 3.6)	46 (5.8)	4.3 (0.0, 9.8)	112 (12.1)	6.3 (2.2, 10.4)	669 (45.2)	1.6 (0.8, 2.5)	473 (36.5)	4.7 (3.0, 6.3)
Face-to-face	3200 (71.1)	3.9 (3.7, 4.1)	749 (94.2)	6.6 (4.9, 8.2)	817 (87.9)	3.8 (2.6, 5.0)	812 (54.8)	3.5 (2.4, 4.5)	822 (63.5)	2.1 (1.2, 2.9)
Total	4500 (100)	3.8 (3.6, 3.9)	795 (100)	6.4 (4.9, 8.0)	929 (100)	4.1 (2.9, 5.3)	1481 (100)	2.7 (2.0, 3.4)	1295 (100)	3.0 (2.2, 3.8)
P-value		0.3375		0.5515		0.2113		**0.0358**		**0.0093**
Season										
Dry**	1690 (37.6)	3.5 (2.6, 4.4)	325 (40.9)	4.6 (2.3, 6.9)	388 (41.8)	5.7 (3.4, 8.0)	625 (42.2)	2.5 (1.2, 3.7)	352 (27.2)	1.7 (0.4, 3.1)
Wet***	2810 (62.4)	3.9 (3.2, 4.6)	470 (59.1)	7.7 (5.3, 10.1)	541 (58.2)	3.0 (1.5, 4.4)	856 (57.8)	2.8 (1.7, 4.0)	943 (73.8)	3.5 (2.3, 4.7)
Total	4500 (100)	3.8 (3.2, 4.3)	795 (100)	6.4 (4.7, 8.2)	929 (100)	4.1 (2.8, 5.4)	1481 (100)	2.7 (1.8, 3.5)	1295 (100)	3.0 (2.1, 4.0)

P-value	0.4775	0.0876	**0.0379**	0.6867	0.0966

*CI (Confidence Interval)
**Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
***Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

Table 2.2 Incidence and prevalence of acute gastrointestinal illness (AGI) in Ethiopia, Mozambique, Nigeria, and Tanzania, October 2020 – September 2021 (n=4500)

		Overall	**Ethiopia**	**Mozambique**	**Nigeria**	**Tanzania**
Annual incidence rate (no. episodes per person-year) (95% CI*)	Unweighted	0.50 (0.42, 0.57)	0.87 (0.63, 1.11)	0.55 (0.37, 0.72)	0.35 (0.24, 0.47)	0.40 (0.27, 0.53)
	Weighted**	0.80 (0.51, 1.07)	1.25 (0.22, 1.92)	1.85 (0.63, 2.80)	0.33 (0.22, 0.43)***	0.42 (0.22, 0.60)
Annual incidence proportion (95% CI*)	Unweighted	0.39 (0.34, 0.44)	0.58 (0.47, 0.67)	0.42 (0.31, 0.51)	0.30 (0.21, 0.37)	0.33 (0.24, 0.41)
	Weighted**	0.55 (0.40, 0.66)	0.71 (0.20, 0.85)	0.85 (0.47, 0.94)	0.28 (0.19, 0.35)***	0.35 (0.20, 0.45)
4-week prevalence (all respondents)	Total cases	166	51	38	38	39
	Unweighted (95% CI)	3.8 (3.2, 4.3)	6.4 (4.7, 8.2)	4.1 (2.8, 5.4)	2.7 (1.8, 3.5)	3.0 (2.1, 4.0)
	Weighted (95% CI)**	6.0 (3.7, 8.3)	9.2 (1.7, 16.7)	13.3 (4.9, 21.6)	2.5 (1.6, 3.4)***	3.2 (1.5, 4.9)
4-week prevalence (web-survey respondents only)	Total cases	41	2	7	10****	22
	Unweighted (95% CI)	3.3 (2.3, 4.3)	4.3 (0.0, 10.3)	6.3 (1.8, 10.8)	1.6 (0.6, 2.6)	4.7 (2.8, 6.6)
	Weighted (95% CI)**	3.1 (1.9, 4.3)	8.9 (0.0, 21.6)	6.2 (0.8, 11.6)	1.6 (0.4, 2.8)***	4.5 (2.0, 7.1)
4-week prevalence (face-to-face respondents only)	Total cases	125	49	31	28	17
	Unweighted (95% CI)	3.9 (3.2, 4.6)	6.6 (4.8, 8.3)	3.8 (2.5, 5.1)	3.5 (2.2, 4.7)	2.1 (1.1, 3.1)
	Weighted (95% CI)**	6.9 (4.0, 10.0)	9.2 (1.3, 17.1)	14.0 (4.8, 23.2)	3.2 (1.9, 4.4)***	2.8 (0.7, 4.8)
Point prevalence	Total cases	27	11	4	4	8

	Unweighted (95% CI)	0.6 (0.4, 0.8)	1.4 (0.6, 2.2)	0.4 (0.0, 0.9)	0.3 (0.0, 0.5)	0.6 (0.2, 1.0)
	Weighted (95% CI)**	0.8 (0.3, 1.3)	1.5 (0.3, 2.7)	1.5 (0.0, 3.6)	0.2 (0.0, 0.4)***	0.6 (0.1, 1.0)
2-week prevalence	Total cases	53	23	17	2	11
	Unweighted (95% CI)	1.2 (0.9, 1.6)	2.9 (1.8, 4.1)	1.9 (1.0, 2.8)	0.1 (0.0, 0.3)	0.9 (0.4, 1.4)
	Weighted (95% CI)**	2.2 (1.9, 2.4)	6.4 (0.0, 13.3)	4.3 (1.1, 7.5)	0.1 (0.0, 0.1)***	0.6 (0.2, 0.9)
2-week diarrhoea prevalence among children below 5 years – the Demographic and Health Survey (DHS) definition*****	Total cases	19	11	5	2	1
	Unweighted (95% CI)	3.7 (2.1, 5.4)	9.0 (3.9, 14.1)	20.8 (4.6, 37.1)	0.6 (0.0, 1.5)	1.8 (0.0, 5.4)
	Weighted (95% CI)**	5.6 (1.9, 9.2)	9.2 (1.8, 16.5)	16.5 (1.4, 31.6)	0.7 (0.0, 1.6)***	0.8 (0.0, 2.3)

*CI (Confidence Interval)
**Weighted for age, gender, and urban/rural status
***Weighted for age and gender only
****Only urban
*****the DHS definition**:** diarrhoea [1 or more loose stools] during the two weeks preceding the survey in children under five years of age [20–23]

Table 2.3 Severity and symptoms among the 166 cases of acute gastrointestinal illness (AGI) in Ethiopia, Mozambique, Nigeria, and Tanzania, October 2020 – September 2021

Severity			**Number (%)**				
			Overall (n=166)	**Ethiopia** (n=51)	**Mozambique** (n=38)	**Nigeria** (n=38)	**Tanzania** (n=39)
Diarrhoea	Experienced any diarrhoea		154 (93.3)	44 (86.3)	38 (100)	35 (92.1)	37 (97.4)
	Had blood in stool		19 (12.9)	8 (18.2)	5 (13.2)	0 (0.0)	6 (16.2)
	Diarrhoea was constant/all day long diarrhoeal episode		10 (6.6)	1 (2.4)	1 (2.6)	4 (11.4)	4 (10.8)
	Ave. maximum no. loose stools in 24 hours (95% CI)		4.1 (3.9, 4.2)	4.4 (3.9, 4.9)	3.7 (3.4, 4.0)	4.3 (4.0, 4.6)	3.8 (3.5, 4.1)
Vomiting	Experienced any vomiting		63 (64.9)	28 (73.7)	7 (63.6)	9 (37.5)	19 (79.2)
	Constant/all day long vomiting episode		4 (7.0)	0 (0.0)	0 (0.0)	3 (37.5)	1 (5.6)
	Ave. maximum no. vomiting episodes in 24 hours (95%CI)		2.9 (2.5, 3.3)	3.2 (2.8, 3.7)	2.3 (1.3, 3.3)	2.6 (1.2, 4.0)	2.8 (1.7, 3.8)
Mean (95% CI) duration of illness (in days)		Unweighted	4.0 (3.5, 4.4)	5.3 (4.4, 6.3)	3.4 (2.3, 4.5)	3.0 (2.3, 3.7)	3.4 (2.6, 4.1)
		Weighted*	3.5 (3.1, 3.9)	4.9 (4.1, 5.6)	2.9 (2.2, 3.6)	3.3 (2.5, 4.0)**	3.9 (3.1, 4.7)
Cases with more than one episode of AGI in the previous 28 days			87 (53.0)	26 (51.0)	25 (65.8)	11 (29.7)	25 (65.8)
Cases admitted to hospital overnight due to the illness			10 (17.5)	1 (6.3)	3 (27.3)	3 (33.3)	3 (14.3)

Cases of AGI who had at least someone sick with AGI in their household	41 (26.3)	17 (33.3)	13 (37.1)	8 (21.1)	3 (9.4)
Other associated symptoms					
Abdominal pain	86 (51.8)	21 (41.2)	31 (81.6)	10 (26.3)	24 (61.5)
Stomach cramp	57 (34.3)	36 (70.6)	8 (21.1)	9 (23.7)	4 (10.3)
Fever	56 (33.7)	23 (45.1)	8 (21.1)	14 (36.8)	11 (28.2)
Headache	34 (20.5)	16 (31.4)	13 (34.2)	3 (7.9)	2 (5.1)
Nausea	20 (12.0)	6 (11.8)	7 (18.4)	1 (2.6)	6 (15.4)
Coughing	15 (9.0)	0 (0.0)	5 (13.2)	5 (13.2)	5 (12.8)
Muscle/ body aches	14 (8.4)	2 (3.9)	5 (13.2)	5 (13.2)	2 (5.1)
Chills	9 (5.4)	1 (2.0)	1 (2.6)	2 (5.3)	5 (12.8)
Runny nose	8 (4.8)	0 (0.0)	0 (0.0)	2 (5.3)	6 (15.4)
Sneezing	6 (3.6)	0 (0.0)	3 (7.9)	2 (5.3)	1 (2.6)
Sore throat	2 (1.2)	0 (0.0)	2 (5.3)	0 (0.0)	0 (0.0)

*Weighted for age, gender, and urban/rural status
**Weighted for age and gender only

Table 2.4 Health seeking behavior and medication use among the 166 cases of acute gastrointestinal illness (AGI) in Ethiopia, Mozambique, Nigeria, and Tanzania (October 2020 – September 2021) and bivariable association between care seeking and medication use among respondents with AGI

	Number (%)				
	Overall (n=166)	**Ethiopia** (n=51)	**Mozambique** (n=38)	**Nigeria** (n=38)	**Tanzania** (n=39)
Cases who sought medical care*	95 (57.2)	30 (58.8)	14 (36.8)	22 (57.9)	29 (74.4)
Cases requested to submitting a stool sample for testing	31 (21.1)	8 (15.7)	2 (5.3)	1 (2.6)	20 (51.3)
Cases who submitted stool sample	29 (17.5)	7 (13.7)	1 (2.6)	1 (2.6)	20 (51.3)
Cases who tested positive	10 (6.0)	1 (2.0)	0 (0.0)	0 (0.0)	9 (23.1)
Cases who took medication for their AGI**	116 (69.9)	31 (60.8)	24 (63.2)	29 (76.3)	32 (82.1)
Cases who sought medical care and took medication**	90 (54.5)	28 (56)	12 (31.6)	21 (55.3)	29 (74.4)

*Medical care includes consultation with general practitioner, after-hours doctors, pharmacist, or Healthline; visit to private clinic, hospital emergency department, health center, or nursing services; or use of alternative health care (e.g., naturopathy, homeopathy, chiropractic, or herbalist)
**Medication they took includes medicine to stop diarrhoea (e.g., Immodium, Lomotil); medicine to stop nausea (e.g., Maxalon, Stemetil); sntibiotics (e.g., Amoxil, Synermox, Erythromycin, Bactrim); or others (e.g., Metronidazole, Paracetamol, medicine to stop malaria, traditional medicine, Azithromycin)

Table 2.5 Odds of having acute gastrointestinal illness (AGI) by demographic characteristic in Ethiopia, Mozambique, Nigeria, and Tanzania, adjusted for all variables in the model, October 2020 – September 2021 (n=3990), significant values at α=0.05 are in bold

Demographic Characteristic	**Coefficient**	**Odds Ratio**	**95% Confidence Interval**
Gender			
Male	0.05	1.05	0.74, 1.49
Female	Ref.	Ref.	Ref.
Age (years)			
0-4	**1.74**	**5.67**	**3.62, 8.88**
5-9	**1.53**	**4.60**	**2.20, 9.65**
10-19	0.48	1.62	0.75, 3.47
20-24	**0.91**	**2.48**	**1.49, 4.15**
25-69	Ref.	Ref.	Ref.
>70	0.60	1.83	0.79, 4.25
Wealth index quintile			
Lowest	0.24	1.23	0.77, 1.96
Second & Middle	Ref.	Ref.	Ref.
Fourth	0.44	1.51	0.97, 2.35
Highest	0.32	1.28	0.81, 2.02
Residence			
Urban	Ref.	Ref.	Ref.
Rural	**0.43**	**1.53**	**1.05, 2.22**
Employment status of main earner in the household			

Working	**0.72**	**2.06**	**1.04, 4.07**
Student	0.65	1.92	0.72, 5.13
Retired	0.81	2.25	0.85, 5.93
Disabled	1.10	3.02	0.60, 15.25
Others	1.88	6.56	0.72, 59.66
Housewife	Ref.	Ref.	Ref.
No. people sleeping per room			
>3	0.25	1.29	0.85, 1.95
≤3	Ref.	Ref.	Ref.
Season			
Dry*	Ref.	Ref.	Ref.
Wet**	0.20	1.23	0.86, 1.74
Country			
Nigeria	Ref.	Ref.	Ref.
Ethiopia	**1.39**	**4.00**	**2.34, 6.83**
Mozambique	**1.31**	**3.70**	**2.12, 6.47**
Tanzania	**0.61**	**1.85**	**1.08, 3.16**
Method of data collection			
Web-survey	**0.59**	**1.80**	**1.08, 3.02**
Face-to-face	Ref.	Ref.	Ref.

*Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
**Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

Table 2.6 Odds of having acute gastrointestinal illness (AGI) by demographic characteristics in Ethiopia, adjusted for all variables in the model, October 2020 – September 2021 (n=748), significant values at α=0.05 are in bold

Demographic Characteristic	**Coefficient**	**Odds Ratio**	**95% Confidence Interval**
Gender			
Male	0.29	1.34	0.68, 2.64
Female	Ref.	Ref.	Ref.
Age (years)			
0-4	**1.66**	**5.27**	**2.61, 10.64**
5-9	**2.03**	**7.58**	**1.41, 40.69**
10-19	0.81	2.26	0.47, 10.76
20-24	0.83	2.30	0.80, 6.59
25-69	Ref.	Ref.	Ref.
>70	0.91	2.47	0.76, 8.10
Wealth index quintile			
Lowest	0.01	1.02	0.40, 2.60
Second & Middle	Ref.	Ref.	Ref.
Fourth	0.55	1.74	0.82, 3.70
Highest	0.06	1.07	0.46, 2.48
Residence			
Urban	Ref.	Ref.	Ref.
Rural	-0.04	0.96	0.51, 1.81
Employment status of main earner in the household			
Working	0.36	1.43	0.60, 3.43

Student	-	-	-
Retired	0.82	2.27	0.55, 9.44
Disabled	-	-	-
Others	-	-	-
Housewife	Ref.	Ref.	Ref.
No. people sleeping per room			
>3	0.31	1.36	0.67, 2.78
≤3	Ref.	Ref.	Ref.
Season			
Dry*	Ref.	Ref.	Ref.
Wet**	0.46	1.58	0.81, 3.10
Method of data collection			
Web-survey	-0.01	0.99	0.21, 4.58
Face-to-face	Ref.	Ref.	Ref.

*Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
**Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

Table 2.7 Odds of having acute gastrointestinal illness (AGI) by demographic characteristics in Mozambique, adjusted for all variables in the model, October 2020 – September 2021 (n=859), significant values at α=0.05 are in bold

Demographic Characteristic	**Coefficient**	**Odds Ratio**	**95% Confidence Interval**
Gender			
Male	-0.30	0.74	0.34, 1.64
Female	Ref.	Ref.	Ref.
Age (years)			
0-4	**1.84**	**6.32**	**1.58, 25.30**
5-9	**3.62**	**37.47**	**4.47, 314.22**
10-19	**1.31**	**3.70**	**1.20, 11.38**
20-24	**1.01**	**2.74**	**1.04, 7.25**
25-69	Ref.	Ref.	Ref.
>70	**2.42**	**11.30**	**1.92, 66.47**
Wealth index quintile			
Lowest	0.11	1.12	0.46, 2.72
Second & Middle	Ref.	Ref.	Ref.
Fourth	-0.75	0.47	0.15, 1.47
Highest	-0.70	0.50	0.18, 1.41
Residence			
Urban	Ref.	Ref.	Ref.
Rural	0.35	1.42	0.63, 3.21
Employment status of main earner in the household			
Working	**2.25**	**9.47**	**1.14, 78.51**

Student	**2.68**	**14.57**	**1.04, 204.14**
Retired	1.28	3.61	0.27, 48.29
Disabled	-	-	-
Others	-	-	-
Housewife	Ref.	Ref.	Ref.
No. people sleeping per room			
>3	0.00	1.00	0.34, 2.96
≤3	Ref.	Ref.	Ref.
Season			
Dry*	Ref.	Ref.	Ref.
Wet**	-0.70	0.50	0.22, 1.12
Method of data collection			
Web-survey	0.02	1.02	0.29, 3.59
Face-to-face	Ref.	Ref.	Ref.

*Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
**Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

Table 2.8 Odds of having acute gastrointestinal illness (AGI) by demographic characteristics in Nigeria, adjusted for all variables in the model, October 2020 – September 2021 (n=1211), significant values at α=0.05 are in bold

Demographic Characteristic	**Coefficient**	**Odds Ratio**	**95% Confidence Interval**
Gender			
Male	0.17	1.18	0.58, 2.40
Female	Ref.	Ref.	Ref.
Age (years)			
0-4	**1.06**	**2.90**	**1.22, 6.89**
5-9	0.74	2.10	0.67, 6.61
10-19	-	-	-
20-24	0.33	1.39	0.16, 12.36
25-69	Ref.	Ref.	Ref.
>70	-	-	-
Wealth index quintile			
Lowest	1.09	2.96	0.94, 9.31
Second & Middle	Ref.	Ref.	Ref.
Fourth	**1.48**	**4.41**	**1.49, 13.00**
Highest	**1.31**	**3.69**	**1.20, 11.42**
Residence			
Urban	Ref.	Ref.	Ref.
Rural	-	-	-
Employment status of main earner in the household			
Working	0.82	2.26	0.29, 17.52

Student	0.66	1.94	0.10, 36.59
Retired	1.51	4.53	0.23, 89.82
Disabled	-	-	-
Others	-	-	-
Housewife	Ref.	Ref.	Ref.
No. people sleeping per room			
>3	0.13	1.14	0.52, 2.49
≤3	Ref.	Ref.	Ref.
Season			
Dry*	Ref.	Ref.	Ref.
Wet**	0.19	1.22	0.58, 2.56
Method of data collection			
Web-survey	-	-	-
Face-to-face	Ref.	Ref.	Ref.

*Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
**Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

Table 2.9 Odds of having acute gastrointestinal illness (AGI) by demographic characteristics in Tanzania, adjusted for all variables in the model, October 2020 – September 2021 (n=1172), significant values at α=0.05 are in bold

Demographic Characteristic	**Coefficient**	**Odds Ratio**	**95% Confidence Interval**
Gender			
Male	0.05	1.05	0.51, 2.17
Female	Ref.	Ref.	Ref.
Age (years)			
0-4	**2.20**	**9.03**	**3.23, 25.25**
5-9	0.52	1.69	0.21, 13.67
10-19	-0.27	0.77	0.10, 6.10
20-24	**1.02**	**2.76**	**1.12, 6.85**
25-69	Ref.	Ref.	Ref.
>70	-	-	-
Wealth index quintile			
Lowest	0.09	1.09	0.35, 3.39
Second & Middle	Ref.	Ref.	Ref.
Fourth	0.49	1.64	0.60, 4.51
Highest	0.57	1.77	0.67, 4.72
Residence			
Urban	Ref.	Ref.	Ref.
Rural	0.66	1.93	0.93, 4.01
Employment status of main earner in the household			
Working	0.17	1.18	0.15, 9.64

Student	0.27	1.33	0.14, 13.14
Retired	-0.04	0.96	0.08, 11.54
Disabled	1.54	4.66	0.35, 62.15
Others	-	-	-
Housewife	Ref.	Ref.	Ref.
No. people sleeping per room			
>3	0.23	1.27	0.43, 3.70
≤3	Ref.	Ref.	Ref.
Season			
Dry*	Ref.	Ref.	Ref.
Wet**	0.51	1.66	0.61, 4.54
Method of data collection			
Web-survey	0.67	1.96	0.71, 5.42
Face-to-face	Ref.	Ref.	Ref.

*Dry season (Ethiopia: October 1 – May 31; Mozambique: April 1 – September 30; Nigeria: November 1 – March 31; Tanzania: June 1 – October 31)
**Wet season (Ethiopia: June 1 – September 30; Mozambique: October 1 – March 31; Nigeria: April 1- October 31; Tanzania: November 1 – May 31)

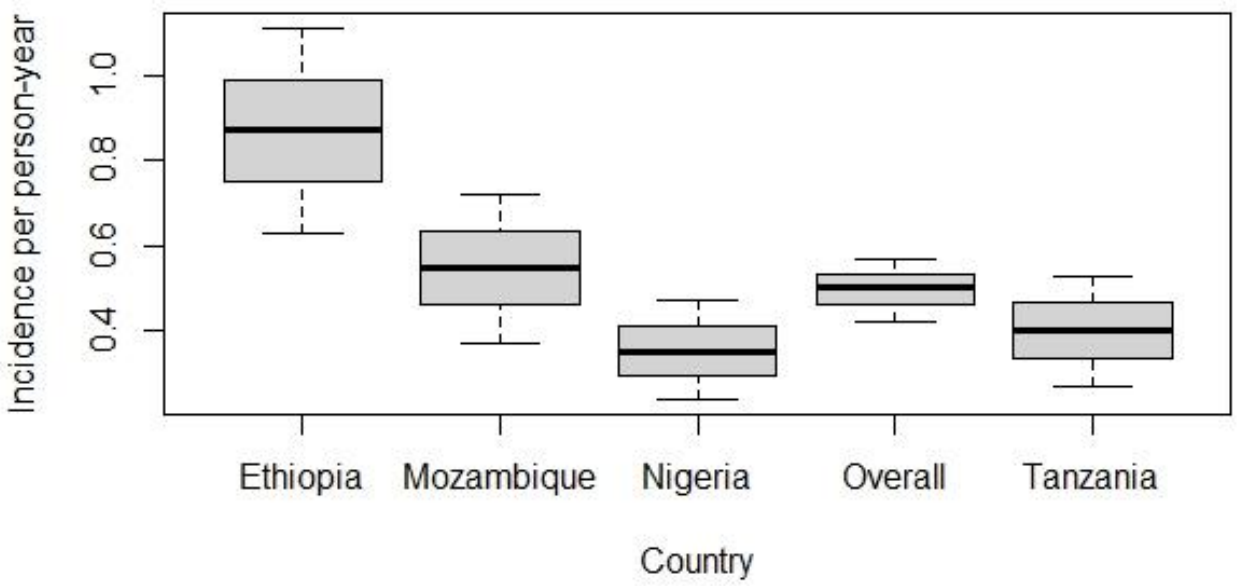

Figure 2.1 Incidence (with the minimum value, the first quartile, the median, the third quartile, the maximum value and 95% confidence interval) of acute gastrointestinal illness in Ethiopia, Mozambique, Nigeria, and Tanzania, and overall, October 2020 – September 2021 (n=4500)

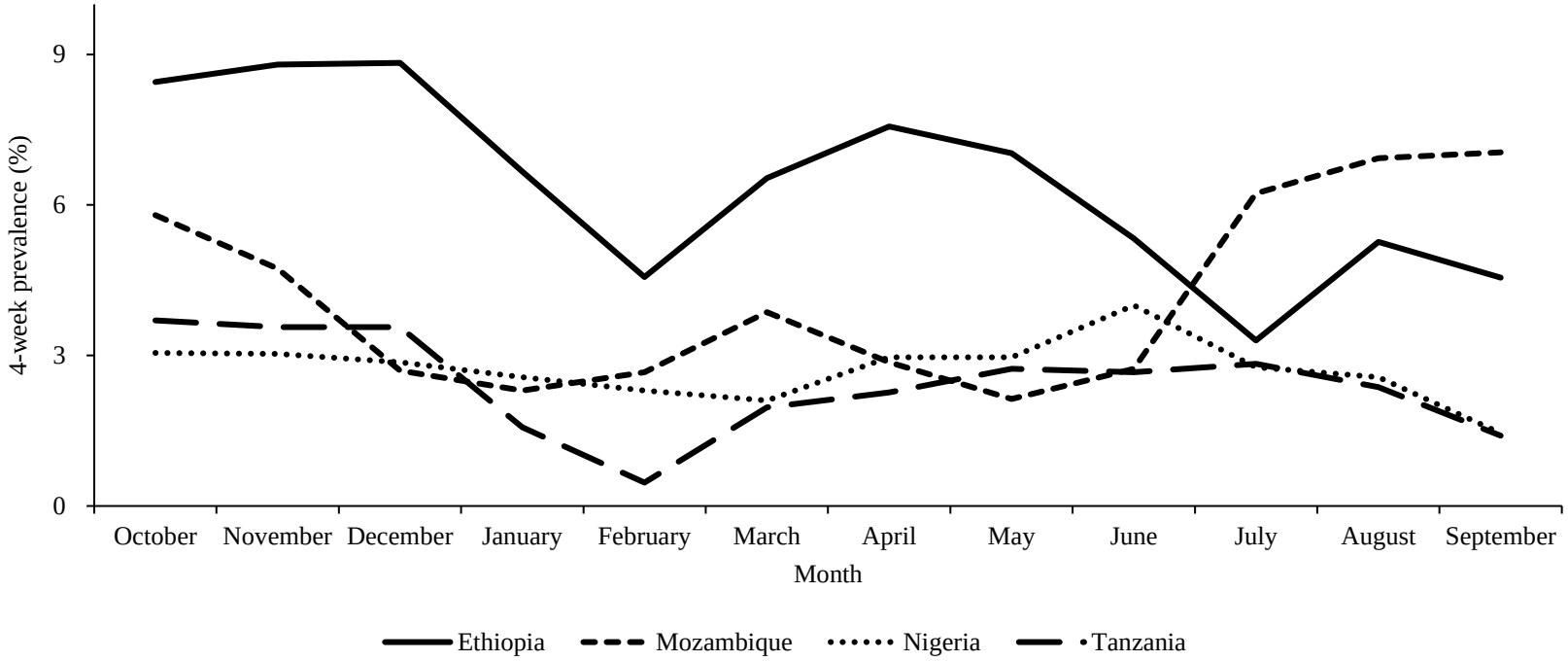

Figure 2.2 Three-month moving average of the 4-week prevalence of acute gastrointestinal illness in Ethiopia, Mozambique, Nigeria, and Tanzania, October 2020 – September 2021 (n=4500)

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Chapter 3

Practicalities of Implementing Burden of Disease Research in Africa: Lessons from a Population Survey Component of our Multi-Partner FOCAL Research Project

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Abstract

Background: Collaborative research is being increasingly implemented in Africa to study health-related issues, for example, the lack of evidence on disease burden, in particular for the presumptive high load of foodborne diseases. The FOCAL (Foodborne disease epidemiology, surveillance, and control in African LMIC) Project is a multi-partner study that includes a population survey to estimate the foodborne disease burden in four African low- and middle-income countries (LMICs). Our multi-partner study team had members from seven countries, all of whom contributed to the project from the grant application stage**,** and who play(ed) specific roles in designing and implementing the population survey.

Main text: In this paper, we applied Larkan et al.'s (2016) framework for successful research partnerships in global health to self-evaluate our project's collaboration, management, and implementation process. Our partnership formation considered the interplay and balance between operations and relations. Using Larkan et al.'s seven core concepts (i.e. focus, values, equity, benefit, communication, leadership, and resolution), we reviewed the process stated above in an African context.

Conclusion: Through our current partnership and research, i.e., implementing a population survey to study disease burden in four African LMICs, we observed that successful partnerships need to consider these core concepts explicitly, apply the essential leadership attributes, perform situational analysis before designing the research, and expect differences in work culture.

Keywords: Partnership, Population survey, Collaboration, Experiences, Africa, Foodborne disease burden

Introduction

Background

The need for multi-partner action research is growing worldwide [1,2], and collaborative research is being increasingly implemented in Africa to study various health issues [3]. In Africa, a collaborative approach is inevitable to address the lack of evidence on disease burden, in particular for the presumptive high load of foodborne diseases [4–7]. Thus, we implemented FOCAL (Foodborne disease epidemiology, surveillance, and control in African LMIC), a multi-partner study to estimate the foodborne disease burden in four African low- and middle-income countries (LMICs): Ethiopia, Mozambique, Nigeria, and Tanzania. FOCAL is an international collaboration of multiple institutions [8], and includes a population survey, which aims to estimate the incidence and distribution of diarrhea in the community in rural and urban settings.

Although collaborative research is desirable, the knowledge and skillset demanded to successfully implement multi-organization studies are still evolving [1,9]. The success of a multi-partner research undertaking mainly relies on the quality of the collaboration [10]. In this paper, we applied Larkan et al.'s framework and seven core concepts (i.e. focus, values, equity, benefit, communication, leadership and resolution) for successful research partnerships in global health [11], to self-evaluate our project collaboration, management, and implementation process to-date, focusing on the population survey, thereby providing insights into the practicability of the burden of disease studies in African settings. Here, we present an overview of FOCAL, describe our population survey working-group, and present the results of our self-evaluation, as well as discuss additional best practices and challenges we encountered that did not fit within the framework.

Overview of the FOCAL Project

Starting with the grant call, the FOCAL project leads from Denmark took the initiative to craft the project's outline, and invited interested collaborators from the four study countries in Africa and supporting partners. Working together, this larger FOCAL team collaborated to design a proposal aimed at facilitating implementation of integrated public health and food-safety surveillance in African LMICs, a priority goal since only a few countries in Africa prioritize implementing surveillance and mitigation strategies to combat foodborne diseases [4,12]. The whole FOCAL team contributed to the project starting from the grant application stage, and our multiple regular meetings enabled the active engagement of all partners at all times. Upon proposal submission, we allocated and finalized the funds required for the research undertakings in each country, including the source of the various budget items. We secured the funding and started the project on November 26, 2018.

FOCAL spans four years, and annual progress reports precede the yearly-allotted release of funds to partner institutions. Any failure by partner institutions to report the achievement(s) per the specified task(s) in time requires justification, to secure the funding for the subsequent year. Among the project's official documents is a work plan outlining specific activities, milestones, and deliverables, with timelines and responsible partner(s). The project's proposal-narrative document incorporated risk mitigation strategies that specified the penalty/consequence of unnecessary delays or lack of contribution to the outlined roles. The Principal Investigator (PI), i.e., the contact person for the funders, monitors activities and achievements, and makes executive decisions when needed. Beyond the original partners named in the grant proposal, postgraduate students and postdoctoral fellows have been enrolled via formal procedures of the respective partner institution, with the PI reviewing candidates' qualifications to ensure

transparency. Partners supervised their trainees' ventures within their respective institution's requirements and timelines vis-a-vis the project's aim. Overall (with the exception of disruptions introduced by the COVID-19 pandemic circa March 2020), there were no substantial flaws in the project activities to-date.

For the population survey, we received clearance from nine ethics committees in six countries, put in place three bilateral data sharing agreements, completed the preparation phase, and commenced survey data collection on February 17, 2020.

The FOCAL Population Survey Working Group

The population survey, like the other component FOCAL studies [8], has a lead and a working group, and the partners from Canada are taking overall responsibility for the population survey component. Designated team members from the four African countries who are part of this working group work closely with the partners from Canada and manage the in country-specific survey activities.

The working group comprises members from Ethiopia, Mozambique, Nigeria, Tanzania, Denmark, Canada, and New Zealand. Partners leading the four country-specific surveys in Ethiopia, Mozambique, Nigeria, and Tanzania are located and affiliated with institutions in the countries. Except for the partner from New Zealand, who resided in Tanzania, the partners from Denmark and one of the two from Canada are also located and affiliated with institutions from these countries. The second partner from Canada is originally from Ethiopia, which was an added advantage to this collaborative work. The partners from Denmark and Canada are experts in the field, who are involved in foodborne disease burden studies in other countries, and also part of the World Health Organization's (WHO) work on the global burden estimates of foodborne diseases, which brought the necessary expertise and experiences to the team.

In general, FOCAL working groups are mostly non-exclusive, where one partner can be a member of several working groups. This helped the population survey working group coordinate with the other working groups to undertake FOCAL's commitments. For this paper, however, we focus on the collaboration within the population survey's working group.

Rationale and Application of Larkan et al.'s Conceptual Framework

Larkan et al. developed a conceptual framework aimed to inform partnerships in global health research [11]. The framework highlights the significance of relational and operational aspects of collaborations and presents viewpoints on seven equally relevant core concepts: focus, values, equity, benefit, communication, leadership and resolution. The framework also outlines the process that most global health research partnerships follow: formation, implementation, monitoring and evaluation. Larkan et al. suggest their framework can inform new collaborations or improve existing ones (like ours), but acknowledge that the framework still needs validation.

We picked Larkan et al.'s framework to self-evaluate our collaborative process, because we found their under-pinning evidence credible and suitable to our collaboration. Specifically, we valued that the framework's development incorporated experience from all LMICs and supporting partners who took part. Additionally, our partnership process suited Larkan et al.'s recommendation for well-functioning collaborations (i.e., agreement on the shared minimum programme, involvement of partners from the design stage, and specific allocation of resources). Finally, we found comparable evidence in other, more recent literature to support the framework's components, which increased our confidence in applying it. We chose to conduct our self-evaluation while in the midst of survey implementation, to identify areas for our own improvement for the remainder of our collaboration. For this purpose, a list of open-ended questions was prepared based on the framework components, with items asking about best

practices and challenges that did not fit within the framework, and then distributed among every partner for completion. The feedback was compiled and then reviewed by each partner. The review took place via multiple rounds for comments to scrutinize the collected information.

Two aspects of the framework made it easy to use in our self-evaluation. First was the elaborated concepts and attributes for desirable partnership qualities, from which their core concepts emerged. Second was the explicit recognition for flexibility in application, to allow contextualization of political, social, and cultural realities. For example, when referring to culture, Larkan et al. emphasized partners' organizational contexts, and we expanded this to also consider work culture related to the local inter-personal and social contexts of our diverse locations.

Main Text

Formation of the Partnership: Operations and Relationships

When our team of researchers from seven countries came together for the first time in the FOCAL project, the driving force that helped us move forward in the collaboration establishment process was a mix of operations and relationships. By operations, we mean that we established our collaboration on a set of activities, which each partner contributed to, with a common goal and shared benefit. Corresponding to Nyström et al.'s observation, the operational aspect of our partnership was largely in place at the formation stage [2]. Here, the formation phase entailed the process starting from the simple communications to initiate the collaboration, to the signing of the sub-grantee agreement between the lead and partner institutions to commence the project activities. Our focus on the project outputs at the formation stage considerably helped us in accommodating the varying work and communication cultures of multiple partners.

Relationships were also key facilitators of the partnership formation process. Partners came together for FOCAL in part via pre-existing connections, a concept described by Duff [13]. For instance, some of our partners worked together on other collaborative projects, which significantly reduced hurdles (e.g., in terms of time, interactions, and trust) and helped nurture additional relationship formation between collaborators. The relationships among partners strengthened as the partners continued working on the early operational features of our collaboration (described above), which aligns with Boucher et al.'s concept of the setting of a shared aim and interest [14]. The interplay and balance between operations and relationships early in our partnership formation enabled smooth survey design, and helped to facilitate survey implementation.

Implementation Phase: The Seven Core Concepts

Below is our assessment of the strengths and gaps in survey design and implementation to-date, by Larkan et al.'s seven core concepts. Overall, we felt the gaps presented below, while important to identify, have not been substantial flaws nor affected FOCAL's deliverables and timeline.

Focus

When designing the population survey (as well as the overall FOCAL project), and as suggested by Leone Sciabolazza et al. [15], we set shared goals and aims of estimating the burden of the foodborne disease in the respective African countries. We perceived that all partners have a common understanding of the population survey's objective, aided by the fact that we are all are researchers in the field who are well aware of the existing knowledge gap concerning the burden of foodborne diseases. Of the project's primary outcomes, a list of the specific survey aims was shared with the working group members by the leads for review. This was revised iteratively by the working group collectively, until each member acknowledged the credibility and achievability of the objectives. The partners also expressed their enthusiasm and determination to produce practical knowledge to share with the scientific community, their respective countries, and Africa broadly. The focus on our shared goals was evident from the emphasis we gave to the process of survey designing, our keenness in providing inputs to developing the survey protocol and tools, and our eagerness and focus on achieving milestones. Moreover, the motivation to enable smooth survey implementation by resource mobilization, the enthusiasm to attend regular meetings, our proactive plan to engage stakeholders in the process, and meeting the survey's timeline were among the examples showing our focus on the shared goals.

In a few instances, we observed a lack of timely execution of specific tasks, even if we had previously reached an agreed timeline at a team level. In general, we acknowledge the need to improve this, but we are mainly focused on building on our successful practices to-date (e.g., shared goal of generating data on the burden of foodborne diseases in African contexts; shared experiences as foodborne disease researchers).

Values

While operating together, we recognized slight variations in work culture, which, as noted by Gélinas [10], is to be expected as we came from different institutions in multiple countries. Situations where these variations were noticeable included inconsistencies in reacting time on action points, sharing accountability on overdue or undone tasks, timeliness on notifying changes or challenges, and voluntarily taking leads on extra responsibilities and delegation of duties. In some instances, we also noted performance variation among our country-specific study teams in the field, which improved when the country collaborators/supervisors are physically present. We preferred not to look at these disparities as challenges or limitations, rather we considered them as an opportunity to share experiences. Fortunately, the open-mindedness of all partners to change(s) enabled us to entertain each variation accordingly. Moving forward, we continue to acknowledge our differences and build on our successful experiences in treating the differences in facilitating the research.

Our partnership, related to Stanley and Anderson's recommendation [9], is built upon trust, which we believe is key to the successful designing and implementation of our survey (beyond the official communications, memoranda of understanding or agreements signed between partner institutions). The partners brought in trust to perform each task, share or delegate responsibilities, mobilize or assign resources, and support each other. Nevertheless, we

also encountered gaps in sharing or delegating responsibilities within the team. We are sometimes inclined to overburden ourselves with multiple activities even when there are official delegates for the respective tasks, thereby delaying the timely completion of assignments. We have identified that we need to be better at sharing responsibilities to maintain our effort in meeting the project's timeline (particularly given the COVID-19, which creates various disruptions that differ by location and over time).

We feel that our level of commitment to perform the tasks and achieve the milestones of executing the population survey is high, and we attribute it in part to our motivation for scientific contribution, our desire to continually strengthen our professional inter-relationships, and the leadership role of the PI. However, we did note that our commitment varies among the partners and over time. For example, while some worked best with tasks having deadlines, others reacted best after a probing/reminder. We all experienced missing meetings without giving advanced notice, and there were also instances where group-level presentations took place without having complete information, due to our untimely response and unavailability. However, we felt that any negative impacts of these variations were minimized in part by having multiple people per institution (thus allowing a 'back up' to be contacted). Moving forward, we need to keep up our dedication to meet our timelines.

Equity

We are inclined to assume that our partnership is inclusive, as a recommended practice for collaborative researches [3,9], because we have been jointly involved in almost every decision made from the formation stage, and each partner appropriately contributed to the work. We also considered students involved in the survey as equitably contributing to decisions, referring to their participation in every meeting and activity as applicable. In some instances, we

also restricted our group-level decisions to pre-determined alternatives based on available evidence, or expertise (e.g., survey design, local acceptability). However, we have not further ascertained whether group-level decisions are reflective of the inclusiveness of each partner's interest. For example, some of us may not have shared thoughts in instances where keen participants urged the group towards a particular decision point. Moving forward, we recognize the need to look into more ways of making sure our decisions are undoubtedly inclusive.

We established the various FOCAL working groups by considering expertise and interest and allowed group members to self-identify (i.e., we left no team members out of the working groups in which they wanted to participate). For example, the overall lead of the population survey was an expert with extensive experience of doing similar population surveys in other countries. We entertained all inputs from each partner with respect and acknowledgment of their expertise at all levels of survey design and implementation to-date, as advised by Stanley and Anderson [9].

When planning the survey data collection and developing the survey tool, we interacted with respect and recognition, and we contracted (i.e., at the project level) a gender specialist to inform the survey and ensure its sensitivity to gender differences across the project cycle. In crafting the field survey, the leads put forward a draft process, which each partner reviewed, and collectively we discussed content and finalized the design. The survey tool was developed in the same way: the leads put forward a draft survey tool, and all partners reviewed each item and provided inputs mainly to contextualize and address country-specific issues. Additionally, each partner took the lead to facilitate translating the survey tool into the respective local languages (Ethiopian – Amharic and Afaan Oromo, Mozambique – Portuguese, Nigeria – Yoruba,

Tanzania – Kiswahili), thereby enabling the smooth survey undertaking. We took this process as evidence that our collaboration relied on and recognized the contribution of each partner.

In an effort to balance potential power differentials that might emerge between the members from the study countries and survey leads (given the credentials of the overall survey lead), different approaches were in place. These approaches included explicitly delineating the stakes of each partner and flexibility in some of our premade decisions. We did not expect any power imbalance, as demonstrated by Essabbar et al. [16], between the study countries, where independent surveys were administered. Having each partner country take a turn to host the FOCAL annual meeting also contributes to power equitability in our collaboration. Despite this, we acknowledged some could experience what Duijs et al. expressed as a sense of disregard [17], considering instances where inputs/comments from partners got refuted with reasoning. Given the partners' level of expertise and experience, refuting inputs could have slightly impacted the sense of ownership, thereby influencing the eagerness and devotion towards achieving our goals. We, as a group of researchers, recognized that we assess every thought put forth in our discussions from our different areas of expertise and experience. Moving forward, we agreed to continue doing this appraisal, as not all ideas can be feasibly implemented.

As described earlier, during the grant writing process, we estimated the required budget for country-specific surveys and made decisions beforehand, which guaranteed the fair sharing of resources among institutions/countries. However, as we finalized the population survey design, we realized we needed to change from web-based only data collection, to both face-to-face and online data collection. To allocate resources to accomplish this, we re-assigned resources from one country's budget to the other, and also reallocated items within a country budget. Thus, the resource sharing took place in consultation and agreement with every partner,

based on pre-set activities and roles, to enable an adequate and fair share of resources. Moving forward, we will also need to scrutinize resource sharing and reallocation due to the COVID-19 pandemic.

Benefit

Starting from the partnership formation stage, as proposed by papers on collaborative research [3,13], we strived to encourage mutual benefits among partners, which resulted from taking part in both the population survey research, and the broader collaboration itself. As partners in a large-scale study in Africa, the experience will be a rewarding one, both to the collaborators and their institutions. The partners from Africa may benefit greatly from this study as it could provide information to enhance control strategies for foodborne diseases (e.g., set a platform to ensure food safety and surveillance of foodborne diseases in LMICs). In this regard, engagement of stakeholders from each study country was planned throughout the project, which included their invitation to our FOCAL annual meetings. Our intent with this is to create a sense of ownership and enable the study outcomes' utilization, thereby letting stakeholders realize the study's contribution to their country. We believe the need to keep engaging the stakeholders inclusively to ensure that our research delivers the intended purpose (e.g., set an advisory group), following an integrated knowledge translation approach [18].

In terms of scientific contributions, the working group members will all be authors on publications coming out of the population survey (unless they decline or choose acknowledgement), and other FOCAL team members will be acknowledged accordingly. This authorship strategy (which also includes prominent inclusion of trainee co-authors) was discussed and agreed on in various team meetings. Moreover, students from member countries have actively participated in the survey design and implementation to-date, thereby allowing

them to develop the research skill to help combat foodborne diseases at various levels. Students will also be lead authors of publications coming out of the survey when they play a leading role on the part that would form their thesis. We acknowledged the need that students involved in country-specific study teams, who play significant roles in our field data collection, be aware of the mutual benefits. We learned the necessity to explicitly assert that we share benefits mutually at all levels of our study-teams.

Communication

Corresponding to the recommended practice in partnerships, we strived to build our partnership with open and transparent communications among partners [10,19]. To-date, we used email, and group voice and video calls for every interaction, and we plan in-person gatherings once in every project year. We also have a common password-protected share web-site at the PI's institution, where all the necessary documents of the project are archived and communally available. We have fortnightly meetings, with circulated agendas beforehand and distributed meeting notes immediately after, on which every partner is free to comment on or provide inputs. We also include explicit action points in meeting notes (with responsible individuals identified) to guide us on the urgent/immediate tasks. At these regular meetings, the lead and each partner give updates on the survey progress and any related notifications. All partners are free to raise any discussion point, and every decision considers all inputs accordingly. So far, partners owned the tasks and took accountability, which helped to evade any power hierarchy, thereby enhancing the openness in our communications. We discussed or informed each other of any issues of the survey components, and also openly discussed and agreed on benefits coming out of it. These efforts, in turn, enhanced our communication in terms of honesty and unambiguity.

On top of regular meetings, partners communicate via email to provide updates, discuss any issues or make enquiries, request support, share documents, follow-up on tasks, and schedule meetings. There is no specific communication chain to follow to make a connection or interact with others on the team; rather, communications are linked by involving project leads and interested team members (by copying in emails), which allows for transparency within our conversations. Our email communications use layman wordings and positive language, and include warm greetings, best wishes, and sometimes sharing of not-too-personal details (e.g., achievements, major life milestones), the latter of which have emerged more recently as a result of the experience sharing. Also, following almost every email was timely feedback with gratitude. Separate voice/video calls were also our alternative communications to facilitate the survey as deemed necessary. Our first in-person meeting to launch the project (held in Addis Ababa, Ethiopia, in February 2019) enabled ease of interaction between ourselves. We also used online training sessions to help bringing everyone on the same page regarding data collection tools and procedures. We believed these collective efforts allowed us to foster further openness and honesty in our communication.

On the other hand, there were instances where we failed to: give feedback urging timely actions/changes; execute decision/action points in a timely manner; attend one-on-one meetings; communicate survey progresses, updates, challenges, or general comments in a timely manner; and actively contribute to group conversations. Furthermore, as time passes, we notice that our responsiveness level declined. This may be due to infrastructure-related issues such as intermittent internet connectivity, sudden overflow of other institutional duties, and other individual-related reasons like variations in task prioritization and social interaction. We

recognized that these gaps are affecting our communication efforts, and moving forward, we are committed to improving each of these gaps.

Leadership and Resolution

In our partnership, we intended to value leadership and resolution attributes suggested for collaborative action research [2,3]. Upon the project's inception, the PI considered credentials when designated the survey lead, in particular, recognized the expertise evident from doing similar surveys in other countries. We outlined the roles and responsibilities of each working group member in the survey protocol. Timeframe and milestones were in place to enable partners to monitor their performances and meet the project's timeline. Partners from each study country managed its budget to accomplish the respective tasks. Signed memoranda of understanding and data transfer agreements, the study protocol, and meeting notes were among formal documents that delineate the duties and accountabilities of each partner. Partners were solely in charge of delivering the respective country-specific milestones, which in turn aided the study process.

Specifically, every partner was mindful of the accountability entailed in accomplishing the tasks. The survey leads guided the activities and oversaw the progress on designated tasks. We tried to apply a delicate leading, probing, or following up roles, which gave due regard to sensitive issues, tactical approaches, and balancing. Overall, the project's lead monitored the activities and played a vital role in balancing the operational and relationship features among partners. As we remarked earlier, hierarchical positionality or power imbalance have not been noticeable in our partnership, which also linked with the full and equitable delegation of tasks. According to Morrison-Smith & Ruiz [20], given the challenge with quality interaction in geographically dispersed study teams, hierarchical leadership is not be the best approach, and empowering the team members is key. We had risk mitigation plans and strategies to deal with

or cope with difficult or challenging situations concerning the survey implementation. As noted above, we set and agreed upon a binding penalty that every partner could face for being unable to comply with or meet the requirement of operating within the timeframe. Even if very unlikely to happen, the penalty extended to the reallocation of funds to other partners/activities.

We continued to deliver the tasks with determination and perseverance, for example, by working out of office hours (to accommodate time zone differences) and on the weekends, voluntarily taking on extra duties, and completing some assignments in advance. We dealt with challenges by being flexible with some premade decisions (e.g., reassigning budget items to distinct tasks) and by investigating alternative ways of executing the action points. The attributes of leadership and strategies of resolution we applied to-date depreciate conflict among partners.

Regardless, we noticed slightly varying performances among ourselves in terms of time and efficiency. For instance, we noted irregularities in the time vs. completeness/contextual appropriateness of survey translations. Also, we encountered variations in the starting date of data collection vs. data quality. The disparities had varying effects and many implications, which we could resolve with attributes linked with management or resolution. These attributes could include activities such as: give due attention to detail in all activities; step-by-step follow up and address concerns; divide tasks into smaller pieces and provide encouragement and recognition for each accomplishment; strengthen technical support as applicable; and create platforms to validate achievements [20]. In general, we perceived that sounder achievements entail multiple aspects, including comprehensive leadership and resolution roles, to which we aspired and strived to fulfil.

Outcomes: Increased Capacity, Influenced Practice and Policy

When considering our survey progress to-date, and Larkan et al.'s core concepts, we foresee short- and long-term research outputs akin to other collaborative efforts [10]. As we are at the earlier stage of survey implementation, the short-term outcome of increased capacity included recruitment of postgraduate students and postdoctoral fellows from partner countries. These trainees are actively engaged in the population survey and work jointly with partners, which eventually will equip them with practical research experience and skills [21]. The experiences and skills could be in designing stand-alone surveys, working within a group of various collaborators, seeing the ups and downs in field surveys, acquiring technical know-how of survey instruments and tools, and developing analysis, reporting, and writing skills. Moreover, they will obtain skills in communication/interaction, evaluation, multidisciplinary thinking, socialization, leadership and resolution. In addition to capacity building, we anticipate that our collaborative effort will contribute to both African and global disease burden reduction efforts, as it will provide evidence to inform policymaking and other changes. We believe that we regularly need to take steps to reinforce our partnership, since we feel that keenness and dedication from every project member and stakeholder in a collective sphere is necessary to achieve the desired outcomes.

Other Best Practices and Challenges

Here, we share other successes, that we put forward as potential best practices, as well as challenges we experienced to-date in our collaboration, that did not directly link with partnership issues explored above.

Best Practices

The leading role of experts with experience in similar surveys reduced many hurdles in the survey design and implementation to-date, akin to Nyström et al.'s recommendation [2]. We discerned that a smooth working relationship with institutional and other stakeholders, as advised by Munung et al. [3], aided the survey process in expediting the research activities, recruiting assistants, students and data collectors, and processing budgets. Moreover, the active cooperation with local community/religious leaders has played a pivotal role in influencing the survey's acceptance/recognition in the community and improving the response rate, and in assisting geographical sub-clustering of study sites.

Mobilization of trained Health Extension Workers (HEWs)/Community Health Workers (CHWs) at the various locations of data collection assisted in engaging local/religious leaders and facilitating survey administration. In some countries, we experienced communities showing more preference when investigators are from health services than a university. These communities even tended to cooperate more when researchers wear lab-coats, which might be due to the assurance they developed from the potential benefits of previous health campaigns. Regardless of our field team wearing or not wearing laboratory-coats, our premade plan of engaging HEWs/CHWs, who are known to the community, proved to be a more suitable approach. Akin to Nyström et al.'s proposal, we also noted that engaging graduate students and empowering them, with the oversight of their supervisors, is an efficient approach to achieve the research. Country-specific on-site data collectors' training, aiming to enlighten them on the uniqueness of each study community, enhanced the data collection process.

Challenges

As noted by others [22,23], we faced technical challenges of implementing a web-based data collection system related to infrastructure (such as limited internet and technology access)

as well as varying levels of literacy in communities. Consistent with Greenleaf et al.'s observation [22], the problem tended to be broader in rural settings with limited internet coverage. Fortunately, using an online survey platform (i.e., Qualtrics), accessed through our partner institution (the University of Waterloo), allowed us to collect data in multiple dialects without the requirement of mobile internet access. Inputting characters of one language to Qualtrics was also a challenge, which we resolved by finding the particular enabler software through web-browsing. Finding specific terms in each language was also a challenge. We utilized a speaker in each majorly spoken dialect but still encountered people speaking other languages in some countries. To resolve this, we formed local study-teams that comprise at least a bilingual member. Moreover, we made the team gender-inclusive to address gender-sensitive issues, additionally alleviating potential security threats faced by data collectors when going alone in some study sites.

Though the details are beyond the scope of this paper, before proceeding to survey data collection, our institutional and national requirements meant we obtained ethical clearances from nine review boards (in six countries), a cumbersome and time-consuming process that required much harmonizing between submissions, particularly when one board required changes. Our plan to mobilize the community via the local leaders was not initially sufficient in some sites, as there were instances of misinformation and coverage incompleteness. To this effect, we obliged ourselves to send out a FOCAL representative to meet with the community leaders to enhance suitable community engagement, which in turn helped us in logistical preparations. We underestimated the number of community leaders needed to access households in some sites, which we need to take into consideration in our ongoing survey implementation. In one country, we faced an unanticipated hurdle, where compulsory recruitment of young males is in place to

join the national army forces. As a result, we could not find young males for the interview for possible reasons related to the compulsory service. Additionally, as we were going out to the field during working/school hours, we have missed some household heads' or in-school children's participation in the survey.

The inability to get up-to-date household registers, difficulty to access sampled households (due to the unevenly dispersed houses and poor road-quality), and participants' expectations for support/incentives were among the challenges we face during face-to-face data collection in some sites. To adjust for the extra resource demand resulting from household inaccessibility, we set a few data collection days per month, as our sample size estimation was considerate of resource constraints.

Conclusion and Suggestions

Here, our multi-partner, multi-country team conducted a self-assessment of our collaboration to-date, using an existing framework for partnership, with the goal of improving our own efforts as well as informing future collaborations. We evaluated our partnership formation, which was bolstered by the interplay and balance between aspects of operations and relationships. One feature of our partnership was a focus on shared goals and aims, where we also identified gaps that require improvement. We elucidated the slight working culture differences of our intercontinental collaboration, and identified trust and commitment as our core values, which we evaluated by signifying the need to build more on enhancing responsibility-sharing and dedication. We assessed our partnership to be inclusive, although we recognized the need to be vigilant in handling inputs from partners and ensuring the inclusiveness of our decisions.

Each of us has acknowledged the mutual benefits of taking part in the survey, with the need to ensure that every team member is well-acquainted with mutual benefits. We illustrated the communication features of our interaction (in terms of openness, transparency, honesty, and unambiguity) while showing the existing communication gaps and our intentions to improve on various components. We unanimously agreed that the leadership attributes (and their dependent resolution strategies) described above worked well, and we acknowledge the need to keep with these same attributes and strategies in our remaining activities.

In general, our assessment to-date suggests that successful partnerships need to consider these core concepts explicitly, apply the essential leadership attributes, perform situational analysis before designing the research, and expect differences in work culture. We suggest Larkan et al. use our application of the framework to help validate it, given our mix, experience/expertise, and fit to its components. Moreover, experiences like ours, when presented with the core concepts and other best practices and challenges, can help inform ongoing and other similar surveys, for example, those aiming to study the burden of foodborne or similar diseases in African or other LMICs.

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Chapter 4

Estimating the Under-ascertainment of COVID-19 cases in Toronto, Ontario, March to May, 2020

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Abstract

Public health surveillance data do not always capture all cases, due in part to test availability and health care seeking behaviour. Our study aimed to estimate under-ascertainment multipliers for each step in the reporting chain for COVID-19 in Toronto, Canada. We applied stochastic modelling to estimate these proportions for the period from March 2020 (the beginning of the pandemic) through to May 23, 2020, and for three distinct windows with different laboratory testing criteria within this period. For each laboratory-confirmed symptomatic case reported to Toronto Public Health during the entire period, the estimated number of COVID-19 infections in the community was 18 (5^{th} and 95^{th} percentile: 12, 29). The factor most associated with under-reporting was the proportion of those who sought care that received a test. Public health officials should use improved estimates, to better understand the burden of COVID-19 and other similar infections.

Background

Since its first case of COVID-19 on January 23, 2020 (1), Canada has experienced at least four epidemic waves to date, with reported cases surpassing 2.1 million as of December 30, 2021 (2). More than one-third of these cases occurred in the province of Ontario, of which about one-third occurred in Ontario's largest city, Toronto (2,3). Given the factors and chain of steps in disease reporting, these case numbers are likely under reported (4–8), for example because individuals do not seek care for their symptoms, or due to changes in testing criteria (6,7,9).

COVID-19, a new disease introduced into a fully susceptible global population, will likely continue to impact population health going forward. To better understand the impact of the pandemic, several studies have estimated the number of individuals who became infected with COVID-19 in the community (6,7,18–21,10–17). Serological surveys, that test for any previous infection with COVID-19, are the most common method used to estimate the number of individuals infected with COVID-19 and are useful when there are asymptomatic cases (10,12,14–21). However, because serological surveys often use small or un-representative population samples, complementing serosurvey findings with estimates of the fraction of cases reported at other steps in the disease reporting chain may allow more valid estimation (22).

This approach to assessing under-ascertainment of notifiable communicable diseases by estimating the fraction of cases captured at each step in the reporting chain has used for foodborne infections and influenza (23–25). Here, we applied this method to COVID-19 cases reported in Toronto, Ontario, Canada, during the first wave of the pandemic, when lab testing was limited to those meeting specific criteria (March to May, 2020). Our objectives were to estimate multipliers for each step in the reporting chain for COVID-19, and overall, to better understand the extent of COVID-19 infection in the general community in Toronto during the

early stages of the pandemic. This methodology may be useful for other stages of the pandemic, such as the wave that began in Ontario in December 2021, driven by the Omicron variant, where demand for laboratory-based PCR testing rapidly exceeded capacity limits, and testing eligibility became restricted primarily to those in high-risk settings (26).

Methods

Approach

COVID-19 cases living in Toronto (outside long-term care facilities) with onset dates any time from the beginning of the pandemic through to May 23, 2020 were included. We chose this end date because lab testing became widely available to anyone with symptoms on May 24, 2020. Given Ontario's testing criteria changed as the pandemic unfolded, we estimated under-ascertainment both overall and for three different testing criteria windows within this period. We used information from three existing datasets to estimate the proportion of cases captured at major steps within the communicable disease reporting chain (Figure 4.1). Because we expected uncertainty in these estimates, we specified proportions using input distributions instead of discrete values (Table 4.1), and multiplied distributions using a stochastic model, taking the inverse to obtain the overall and testing window-specific under-ascertainment estimates. We also calculated step-specific under-ascertainment estimates by multiplying proportions at higher steps in the reporting chain and taking the inverse. Assumptions and analytic decisions were explored in a sensitivity analysis (Appendix E; Table E1) and final under-ascertainment estimates were compared to those from serosurvey data for the same timeframe and population (27). We used a seroprevalence study from Public Health Ontario (27) to determine the ratio of the estimated number of cases in the total population to the number of cases reported to TPH and compared the

resulting ratios to our model-based estimates. This study received ethical clearance from a University of Waterloo Research Ethics Committee (#42591).

Time Windows

The first time window was up to and including March 12, 2020, when testing was offered to only those with symptoms consistent with COVID who also had: travelled to an impacted area; close contact with a confirmed or probable COVID case; or close contact with a person with acute respiratory illness who had been to an impacted area. Health providers could request testing outside of these parameters based on assessment and clinical judgement (28).

The second window was between March 13 to April 9, 2020, where priority testing was done for people who: had severe symptoms and thus required hospitalization; were health care workers or who work in a health care setting; were first responders (police officer, firefighter, paramedic, correctional officer, parole officer or probation officer); were at high risk (i.e., people with lung or heart disease, diabetes or health conditions that affect their immune system); or were living in congregate living facilities. Travel history was no longer a criterion for testing. Mildly symptomatic individuals were asked to self-isolate at home and were not prioritized for testing (29).

The third window was between April 10 to May 23, 2020, where the criteria from the second window were extended to include people who were: essential workers; residents/staff of homeless shelters or group homes; or living with health care workers (30). In this window, there was an additional criterion announced on April 15, 2020, which added enhanced/surveillance testing of all residents and staff in long-term care homes (31); however because our data did not include information for these people specifically, this criterion was ignored in this analysis.

Data Sources

We used three datasets: Toronto's notifiable disease surveillance data on reported cases of COVID-19 (de-identified) from January to May 2020 ("reported case data"); weekly counts of the number of COVID-19 tests completed and numbers testing positive in Toronto from January to May 2020 ("weekly testing data"); and a survey of the general population conducted by Toronto Public Health in April and May 2020 ("population survey data").

The reported case data included information on case classification (confirmed, probable), gender (male, female, transgender, other, unknown), symptomatic status (symptomatic, asymptomatic, unknown), age, specimen collection dates (range: January 23, 2020 to May 23, 2020) and reported dates (range: January 23, 2020 to May 23, 2020). Of the 9,014 cases of COVID-19 reported in the general community, 6,217 (72.2%) were symptomatic, of which 5,530 (90.1%) were laboratory-confirmed and were thus included in our analysis. We excluded probable cases that did not have laboratory confirmation, as a criterion for being defined as a probable case required symptoms which would increase the proportion symptomatic. For the 5,530 cases, all variables were 100% complete with the exception of specimen collection date, which was missing for 24 (0.43%) cases.

Weekly COVID-19 testing data from the Ontario Laboratory Information System were received from the Institute of Clinical Evaluative Sciences (32), and included weekly tallies of the number of people with a positive test result outside of long-term care settings. For individuals with more than one confirmed positive COVID-19 test, only the first testing episode (specimen collected, test positive) was included in the weekly counts. We included 19 complete weekly counts in our analysis (from January 12 to May 23, 2020), comprising 6,929 people testing positive. Because any numbers less than six were suppressed to protect privacy, there were two

weeks (January 19-25, 2020 and February 16-22, 2020) where the numbers of people testing positive were suppressed.

The population survey was administered through Toronto Public Health's public-facing website (33) in April and May 2020, using CheckMarket survey software (Checkmarket®, Turnhout, Belgium (34)). The survey was publicized via social media and collected information on COVID-19 symptoms between March 1 to May 25, 2020. For Toronto residents reporting symptoms, the survey then asked about: age; gender (male, female, transgender, "other"); symptoms; the dates symptoms began and resolved; and possible exposures (i.e., travel history outside Canada within 14 days of symptoms onset, any contact with either a confirmed COVID-19 case or an individual with COVID-19 symptoms who was not tested for COVID-19, health care worker or worker in the health care setting, first responder, worked with homeless clients, provided essential services, or interacted with the public). The survey also asked about: testing for COVID-19; care seeking (visited an emergency department or an assessment center; contacted Telehealth, Toronto Public Health, or their family physician); and chronic or other underlying medical conditions.

A total of 3,532 (~0.12% of the Toronto population) people completed the survey between April 2 and May 25, 2020, of whom 3,529 (99.9%) reported living in Toronto. Of these, 2,302 (65.2%) provided their symptomatic status, of whom 1,444 (62.7%) reported having symptoms of COVID-19. Data completeness by variable is given in Appendix F Table F1. After data manipulation (see Appendix G, "Additional Notes on Data Sources"), the remaining 1,433 symptomatic respondents had onset dates from September 27, 2019 to May 30, 2020, and resolved dates from January 2 to June 5, 2020. Of the 1,433 symptomatic respondents, 360 (25.1%) reported neither onset nor resolved dates, and 11 (0.8%) reported impossible dates (n=4,

onset or resolved date after the survey date; n=7, onset date after resolved date). We excluded these 371 people from our main analysis.

Analysis

We used SAS 9.4 (SAS Institute, Cary, NC) to perform data manipulation and calculate parameters for input distributions (Table 4.1), as described below. We generated under-ascertainment estimates using Monte Carlo simulation modelling with 10,000 iterations in R version 4.0.2. For the time window-specific analyses, data were matched to time windows (Appendix F, Table F2). Population survey respondents and reported COVID-19 cases who were missing data for specific variables were excluded from the analysis of that variable. We treated suppressed weekly count numbers as zeros in the main analyses.

Proportion of those who test positive who were reported to Toronto Public Health

The input distribution for the proportion of those who test positive who were reported to Toronto Public Health was determined using the weekly count data and reported case data. We parameterized a beta distribution where the denominator was the number of positive tests within the testing window. Two of these counts spanned two testing windows; for these, we assumed numbers were evenly distributed across the seven days, and divided these numbers between testing windows proportional to the fraction of days per testing window. For example, testing week March 8 to 14 spanned testing window one (5 days) and two (2 days), thus 5/7 of the number of positives were assigned to testing window one and 2/7 to testing window two. The numerator was the number of COVID-19 cases reported during the testing window. This was determined using the reported dates in the reported case data (Appendix F, Table F2). For the overall estimate, the denominator and numerator were total number of positive tests, and total number of COVID-19 cases reported, respectively.

Proportion of those who were tested that tested positive

The input distribution for the proportion of those who got tested that tested positive was estimated by applying COVID-19 test sensitivity. The test in use to detect COVID-19 in Ontario, Canada, was polymerase chain reaction (PCR) with varieties including real-time (qPCR), real-time reverse-transcriptase (rRT-PCR), and reverse transcriptase (RT-PCR) (35). We used reported test sensitivities for these tests: qPCR of 71% (36); rRT-PCR range from 70.7% to 83.3% (37,38); and RT-PCR range from 71% to 88% (39). We parameterized a uniform distribution with minimum (70.7%) and maximum (88%) test sensitivity values.

Proportion of those who sought care that got tested

The input distribution for the proportion of those who sought care that got tested was determined using information from several sources. We started with the population survey, where the denominator was the number of individuals symptomatic during the testing window who reported seeking medical care, estimated as those who reported that they: went to an emergency department or an assessment center; called Telehealth (i.e., Ontario's free telephone service to get health advice or information from a Registered Nurse); contacted Toronto Public Health; or contacted their family physician. The numerator was the subset who were tested, as reported in the survey. For the overall estimate, the denominator and numerator were the total number of respondents (counting only those who met the testing criteria at least once in any of the windows) who reported seeking care and getting tested, respectively, regardless of whether they were able to be matched to a testing window. However, in the context of the global pandemic, the estimates (range: 0.17-0.23) look too small. Thus, unlike the underreporting estimation of foodborne illnesses, we decided to use these numbers as minimum values in pert distribution and the maximum value to be 1 (100%). The most likely value we used was the

highest proportion (i.e., 75%) during a pandemic, as reported by Reed et al.'s paper on influenza A pandemic (H1N1) (40), for the proportion of persons seeking care with a specimen collected.

Proportion of those who met the testing criteria who sought care

The input distribution for the proportion of individuals who met the testing criteria who sought care was determined using population survey data. We parameterized a beta distribution, where the denominator was the number of symptomatic individuals within the testing window who met the testing criteria. The numerator was the subset who sought medical care. For the overall estimate, the denominator and numerator were the sum (counting only those who met the testing criteria at least once in any of the windows) of the testing window-specific denominators and numerators, respectively.

Proportion of those with symptoms who met the testing criteria

The input distribution for the proportion of those with COVID-19 symptoms who met the testing criteria was determined using information for symptomatic individuals from the population survey. We parameterized a beta distribution, where the denominator was the number of individuals symptomatic during the testing window. This was determined using reported onset and resolved dates (Appendix F, Table F2) where individuals were included in the testing window if either (a) their onset and resolved dates encompassed some or all of the testing window (meaning some individuals could contribute data to more than one testing window), or (b) for those with only one date, said date fell within the window. The numerator was the subset of individuals with COVID-19 symptoms who met the testing criteria for the window. Finally, for the overall estimate, the denominator was all those who were symptomatic (regardless of whether they were able to be matched to a testing window), and the numerator was the number of people who met the testing criteria at least once in any of the windows.

Proportion of those with COVID-19 in the community who were symptomatic

The input distribution for the proportion of those with COVID-19 in the community who were symptomatic was determined using the proportion symptomatic in the reported case data; we prioritized using data from the study population and timeframe, since values from the literature from other similar settings reported highly varying asymptomatic proportions (ranges: 20% to 76%; Appendix F, Table F3). We parameterized a beta distribution, where the denominator was the number of confirmed COVID-19 cases reported to Toronto Public Health between January 1 and May 23, 2020. The numerator was number of these cases who were symptomatic.

Results

The cumulative numbers of illnesses at each step in the reporting chain are given overall and by testing window (Table 4.2). The density distribution curves for the under-ascertainment estimates (Figure 4.2) show that the under-ascertainment improved across the three testing windows, and uncertainty about the multiplier estimates decreased. For the overall window, we estimated a median of 17 and a mean of 18 individuals with COVID-19 in the community for each symptomatic, laboratory-confirmed COVID-19 case reported to Toronto Public Health. Thus, the 5,530 symptomatic, laboratory-confirmed cases reported to Toronto Public Health represented an estimated ~ 99,540 (5^{th} and 95^{th} percentile: 66,360, 160,370) community cases of COVID-19 from March to May 2020. Uncertainty about the proportion of those who sought care that received a test was made the highest contribution to the uncertainty of the overall under-ascertainment rate (Table 4.3). Although our estimated under-ascertainment multiplier (18) was higher than that from the COVID-19 seroprevalence study for Ontario during the same

timeframe (11; Table 4.4), our estimate and its uncertainty interval (18; 12, 29) fell within the estimated rage of values when using seroprevalence data (2, 47).

Discussion

Our study estimated under-ascertainment multipliers for each step in the reporting chain for COVID-19 in Toronto, Canada, from March to May 2020. Our analysis suggests that tens of thousands of COVID-19 infections occurred in the community during the earlier phase of the pandemic, before lab testing became widely available, and that approximately 5.6% of COVID-19 infections were captured through routine public health disease surveillance during this early pandemic phase (March – May 2020). A nation-wide study in the US that used similar methods estimated 13% of community cases were captured through PH disease surveillance, although their study period extended until the end of September 2020 (11). This lower estimated under-reporting in the US study may reflect improved case ascertainment as the pandemic unfolded, as both the US study and ours demonstrated decreased uncertainty in the under-ascertainment multiplier, and improved case capture, across study time periods. The difference may also be due to differences in test sensitivity particularly given the US study's longer duration or potentially more COVID-19 cases in US, and differences in laboratory access, health-seeking behaviour, data sources, test eligibility, and other factors.

Here, we used stochastic modelling of the fraction of COVID-19 cases captured at each step in the reporting chain to estimate the under-ascertainment of COVID-19 in Toronto. While this method, used for foodborne infections and influenza (23–25), yielded slightly higher estimates than those reported in a COVID-19 seroprevalence study for Ontario during the same timeframe (27), the differences were not significant. Interestingly, we observed that the ratio from the seroprevalence study was lower (4.7) at the starting period and higher (22.6) at the end

and was vice versa for the model-based estimates. The increasing pattern from the seroprevalence estimates could be due to the varying antibody response in those infected individuals that allowed more serum residue detection rate at the later stage than the cases captured in the surveillance system. On the other hand, in our study, as time passed, test availability improved, and more people were able to get tested and counted in the reports, reducing the model-based multiplier estimates. Regardless, estimates from serologic surveys can be limited by selection bias in the screened population and the varying antibody response with lasting time and specimen type. Using multiple data sources would facilitate a better understanding of the burden of COVID-19 infection.

Our study is subject to four limitations. First, the population survey used to understand individuals' care-seeking was web-based and self-selected. Participants, who might be different from those who chose not to participate or did not have access to the survey, could have altered the estimates in both directions. Second, we used symptomatic proportion (~95%) from the reported case data, which was higher than any of those reported by studies in the literature (range: 23% to 80%) since those who got captured in a surveillance system are highly likely to be symptomatic individuals. Third, the proportion of those who sought care that got tested was not very accurate and most influential but should be improved. Lastly, our estimates might not reflect the situation in the entire city as Toronto's population is not homogenous (e.g., the difference in socioeconomic status) vis-à-vis COVID-19 infection rate (41).

Despite these limitations, our study employed a method that allowed us to account for our uncertainty about the actual values of the proportions reported at the steps in the reporting chain, using available data sources. Moreover, our approach enables local health units to identify the steps in the reporting chain at which cases are undercounted. This can be adapted to various

contexts, including those related to new variants, added tools (e.g., rapid antigen tests), and even other changes to health seeking behavior. To conclude, during the first wave of the COVID-19 pandemic, only a fraction of the total COVID-19 cases occurring in the community was reported to Toronto Public Health, with an estimated 18 infections occurring in the community for each COVID-19 case reported to the local public health unit. As reported numbers do not reflect the actual infection rate in the community, policymakers, program planners, and local public health units should consider the ratio of reported versus potential missed cases in such infectious disease outbreaks.

Table 4.1 Input distributions for, and mean estimates of, the proportions reported at each step in the reporting chain, in the model to estimate under-ascertainment rate of COVID-19 cases in Toronto, Ontario, Canada, March to May, 2020

Reporting Chain Step (Data Source)	**Time**							
	Entire timeframe		**Testing Criteria Window**					
			Up to March 12, 2020		**March 13 to April 9, 2020**		**April 10 to May 23, 2020**	
	Input Distribution (parameters)*	Mean (5^{th}, 50^{th}, 95^{th})	Input Distribution (parameters)	Mean (5^{th}, 50^{th}, 95^{th})	Input Distribution (parameters)	Mean (5^{th}, 50^{th}, 95^{th})	Input Distribution (parameters)	Mean (5^{th}, 50^{th}, 95^{th})
Proportion of those who test positive who were reported to Toronto Public Health (, ***)**	Beta (5530+1, 6929-5530+1)	0.798 (0.790, 0.798, 0.806)	Beta (57+1, 87-57+1)	0.651 (0.566, 0.653, 0.732)	Beta (1341+1, 1709-1341+1)	0.784 (0.768, 0.784, 0.801)	Beta (4132+1, 5133-4132+1)	0.805 (0.796, 0.805, 0.814)
Proportion of people with COVID-19 who	Uniform (0.707, 0.880)	0.794 (0.716, 0.796, 0.872)	Uniform (0.707, 0.880)	0.794 (0.716, 0.796, 0.872)	Uniform (0.707, 0.880)	0.794 (0.716, 0.796, 0.872)	Uniform (0.707, 0.880)	0.794 (0.716, 0.796, 0.872)

tested positive-test sensitivity (****)								
Proportion of those who sought care that got tested (*****)	Pert (0.17, 0.75, 1.00)	0.695 (0.425, 0.708, 0.920)	Pert (0.18, 0.75, 1.00)	0.699 (0.434, 0.710, 0.922)	Pert (0.16, 0.75, 1.00)	0.689 (0.417, 0.702, 0.914)	Pert (0.22, 0.75, 1.00)	0.703 (0.446, 0.713, 0.918)
Proportion of those who met the testing criteria who sought care (*****)	Beta (168+1, 461-168+1)	0.365 (0.328, 0.364, 0.403)	Beta (34+1, 87-34+1)	0.394 (0.310, 0.393, 0.478)	Beta (131+1, 331-131+1)	0.397 (0.353, 0.396, 0.441)	Beta (46+1, 128-46+1)	0.362 (0.294, 0.362, 0.433)
Proportion of those with COVID symptoms who met the testing criteria (*****)	Beta (461+1, 1062-461+1)	0.434 (0.409, 0.434, 0.459)	Beta (87+1, 262-87+1)	0.330 (0.284, 0.329, 0.378)	Beta (331+1, 871-331+1)	0.381 (0.354, 0.380, 0.408)	Beta (128+1, 224-128+1)	0.570 (0.516, 0.571, 0.625)
Proportion of those with COVID-19 in the community who	Beta (8091+1, 9701-8091+1)	0.834 (0.828, 0.834, 0.840)	Beta (8091+1, 9701-8091+1)	0.834 (0.828, 0.834, 0.840)	Beta (8091+1,	0.834 (0.828, 0.834, 0.840)	Beta (8091+1,	0.834 (0.828, 0.834, 0.840)

were symptomatic (**)					9701-8091+1)		9701-8091+1)	

*The types of distribution (parameters): Beta (numerator+1, denominator-numerator+1); Uniform (minimum, maximum); Pert (minimum, most likely value, maximum).
**Toronto Public Health notifiable disease surveillance data, January-August, 2020.
***Weekly count data of COVID-19 diagnostic test recipients and positives, January-September, 2020.
****Published studies (36–39).
*****COVID-19 population survey conducted by Toronto Public Health, April-May, 2020.

Table 4.2 Estimated cumulative number of COVID-19 cases captured at each step in the reporting chain and occurring in the community for each case of COVID-19 reported to Toronto public health, Ontario, Canada, March to May, 2020.

Reporting Chain Step	**Mean (5^{th}, Median, 95^{th})**			
	Entire timeframe	**Testing Criteria Window**		
		Up to March 12, 2020	**March 13 to April 9, 2020**	**April 10 to May 23, 2020**
Reported to Toronto Public Health	1 (1, 1, 1)	1 (1, 1, 1)	1 (1, 1, 1)	1 (1, 1, 1)
Test detects COVID-19	1.253 (1.241, 1.253, 1.266)	1.545 (1.367, 1.531, 1.766)	1.275 (1.249, 1.275, 1.303)	1.243 (1.229, 1.242, 1.257)
Tested	1.584 (1.438, 1.577, 1.752)	1.953 (1.656, 1.935, 2.313)	1.612 (1.460, 1.604, 1.783)	1.570 (1.425, 1.562, 1.738)
Sought care	2.419 (1.678, 2.240, 3.782)	2.954 (1.995, 2.745, 4.598)	2.485 (1.719, 2.290, 3.861)	2.348 (1.672, 2.193, 3.547)
Met the testing criteria	6.652 (4.520, 6.159, 10.425)	7.636 (4.796, 7.102, 12.317)	6.289 (4.241, 5.804, 9.936)	6.580 (4.370, 6.175, 10.290)
Had COVID-19 symptoms	15.340 (10.337, 14.208, 24.083)	23.351 (14.100, 21.634, 38.072)	16.551 (11.080, 15.258, 26.140)	11.574 (7.566, 10.859, 18.087)

COVID-19 cases in the community	18.395 (12.390, 17.044, 28.897)	28.001 (16.910, 25.963, 45.557)	19.846 (13.292, 18.295, 31.307)	13.879 (9.074, 13.019, 21.661)

Table 4.3 Correlation between the distribution of the overall under-ascertainment multiplier and the input distributions for the step-specific proportion in the reporting chain (for the entire time period only and presented in descending order of correlation), Toronto Public Health, Ontario, Canada, March to May, 2020

Proportion	**Correlation Coefficient (Pearson's)**	**Significance (α=0.05)**
Tested	0.913	<0.001
Sought care	0.259	<0.001
Test detects COVID-19	0.258	<0.001
Met the testing criteria	0.152	<0.001
Reported to Toronto Public Health	0.038	<0.001
Had COVID-19 symptoms	0.036	<0.001

Table 4.4 COVID-19 seroprevalence, number of cases in the total population, and infection under-ascertainment ratio of reported cases to estimated number of cases in Toronto, Ontario, Canada, by time period, March to May 2020

Age and Sex Category		**Seroprevalence estimates by Public Health Ontario (95% CI)** (27)	**Total population in Toronto** (32)	**(A) Estimated number of cases in the total population using seroprevalence estimates (95% CI)**	**(B) Number of cases reported to TPH**	**Ratio of (A) to (B) (95% CI)**
March to April 2020						
0-19 years	Male	0.0 (0.0, 4.5)	293,536	0 (0, 13209)	28	UTD* (UTD, 471.75)
	Female	0.0 (0.0, 4.3)	278,027	0 (0, 11955)	29	UTD (UTD, 412.24)
20-59 years	Male	0.8 (0.02, 4.2)	872,532	6980 (175, 36646)	1331	5.24 (UTD, 27.53)
	Female	0.0 (0.0, 1.2)	900,041	0 (0, 10801)	1125	UTD (UTD, 9.60)
≥60 years	Male	2.8 (0.3, 9.7)	324,386	9083 (973, 31465)	490	18.54 (1.99, 64.21)
	Female	0.0 (0.0, 6.3)	387,204	0 (0, 24394)	410	UTD (UTD, 59.50)
Total			3, 055, 726	16063 (1148, 128470)	3413	4.71 (UTD, 37.64)

May 2020						
0-19 years	Male	0.0 (0.0, 4.4)	293,536	0 (0, 12916)	43	UTD (UTD, 300.37)
	Female	1.4 (0.2, 4.8)	278,027	3892 (556, 13345)	64	60.81 (8.69, 208.52)
20-59 years	Male	1.6 (0.4, 4.1)	872,532	13961 (3490, 35774)	760	18.37 (4.59, 47.07)
	Female	2.6 (0.6, 4.7)	900,041	23401 (5400, 42302)	724	32.32 (7.46, 58.43)
≥60 years	Male	1.1 (0.1, 4.0)	324,386	3568 (324, 12975)	258	13.83 (1.26, 50.29)
	Female	0.5 (0.01, 2.9)	387,204	1936 (39, 11229)	217	8.92 (UTD, 51.75)
Total			3, 055, 726	46758 (9809, 128541)	2066	22.63 (4.75, 62.22)
Overall (March to May 2020)						
			3, 055, 726	62821 (10957, 257011)	5479**	11.47 (2.00, 46.91)

*UTD – Unable to determine because the denominator was lower than the numerator

**5479 was smaller than the total cases (5530) used in the model, because there were people with other gender categories than male/female in the reported case data, but the serosurvey reported in male/female categories only.

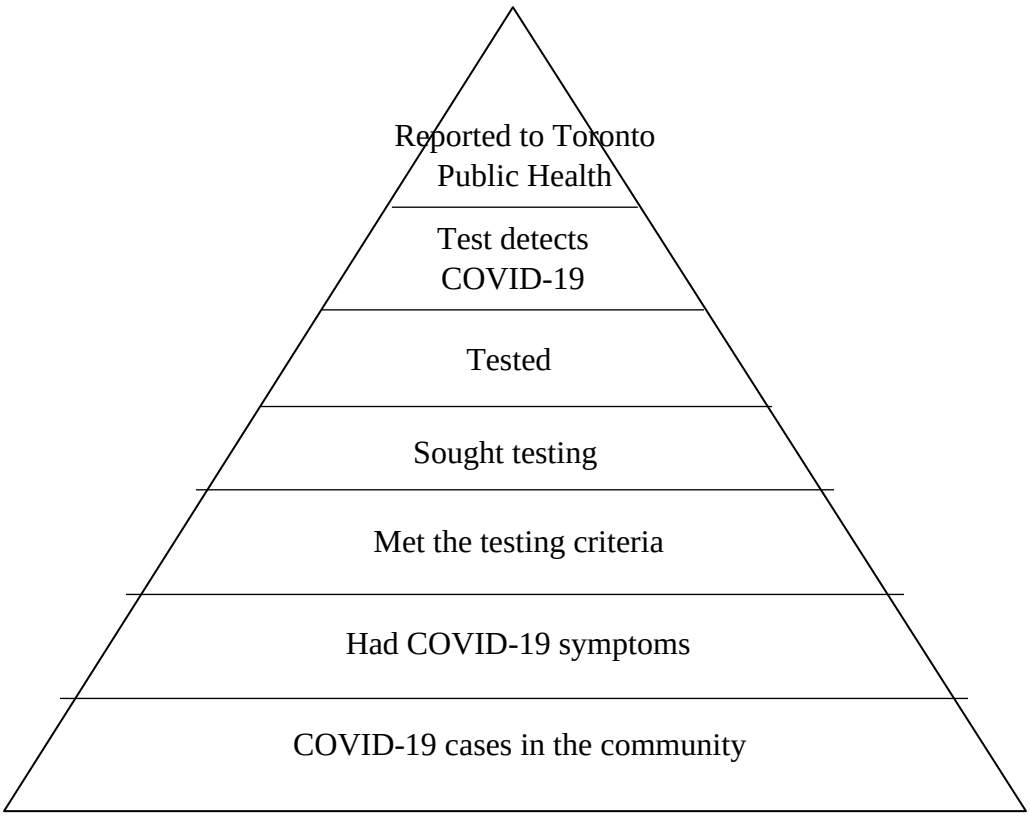

Figure 4.1 Reporting pyramid for COVID-19 in Toronto, Ontario, showing the sequential steps necessary for case capture in the local public health surveillance system, March to May, 2020

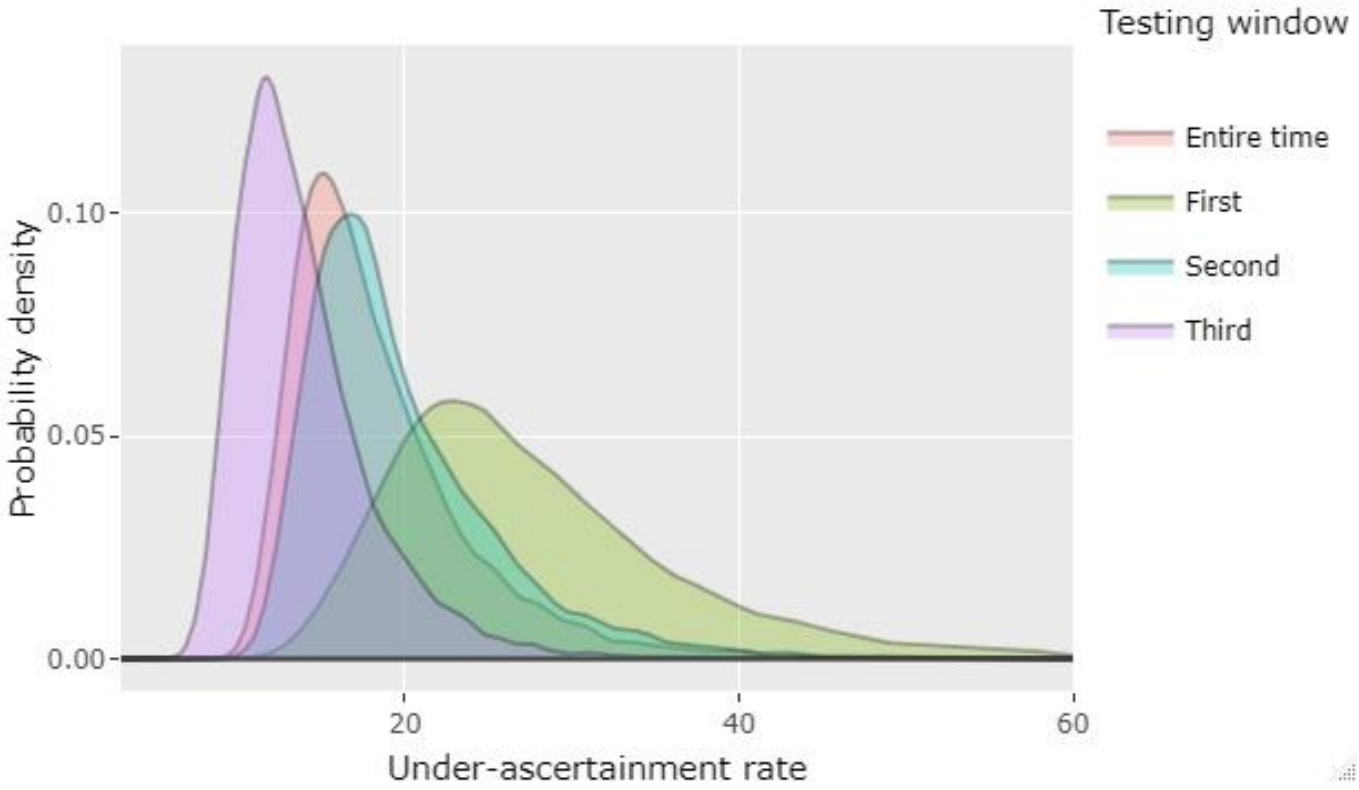

Figure 4.2 Distribution of the estimated overall under-ascertainment rate (for the different windows and entire time period) of COVID-19 cases in Toronto, Ontario, showing the number of COVID-19 illness in the community for each case reported to Toronto Public Health, Ontario, Canada, March to May, 2020.

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Chapter 5: General Discussion

Overview

Every year, 1 in 10 people are affected by AGI caused by food globally. The burden is severe in low-and-middle-income countries (LMIC), mainly African LMIC. Except for the crude reports, and aggregate-level data, there is a lack of accurate data on AGI in Ethiopia, Mozambique, Nigeria, and Tanzania. Accurate estimates of the epidemiology of AGI are necessary to inform a nation's decision and resource allocation. For this purpose, this thesis estimated the epidemiology of AGI in the general population of Ethiopia, Mozambique, Nigeria, and Tanzania (Chapter 2), evaluated the multi-national collaborative process used to achieve the first objective (Chapter 3), and as a secondary aim due to the interruption of this research by the COVID-19 pandemic, explored the application of methods typically used to adjust for under-reporting of foodborne infections [1–3] to COVID-19 (Chapter 4).

Summary of key findings

The population survey (Chapter 2) revealed the estimates of the epidemiology of AGI at the population level using an internationally comparable case definition in African LMIC. This study showed the significant public health burden of AGI in the study communities of Ethiopia, Mozambique, Nigeria, and Tanzania, with estimates of incidence and prevalence of AGI comparable to other LMICs. After applying the DHS case definition, the prevalence estimate of diarrhea was inconsistent with those reported in the study country's DHS reports. The severity of AGI, as measured by mean duration of illness and the average maximum number of loose stools and vomiting episodes in 24 hours, in this study was comparable or slightly greater than those reported in other LMICs. Except in one country (i.e., Nigeria), more than half of AGI cases in the study countries sought medical care, which is higher than those reported in other LMICs (China,

Argentina, Chile, Saint Lucia, Trinidad and Tobago, and Barbados); however, this may have been due to the information distributed by worldwide researchers or the public health officials of the respective countries to the public that linked AGI with COVID-19 symptoms during the pandemic, thereby making individuals with such information to seek more care for their AGI symptoms than they would have before the pandemic.

In contrast to some studies in other LMICs, in this study, the occurrence of AGI did not show a variation between wet and dry seasons (as defined by each study country) either in the univariate or multivariate analysis.

Consistent with studies in other LMICs, children aged less than five years had the highest prevalence of AGI compared to other varying age groups in this study, adjusting for other factors like gender, wealth, urban/rural status, employment status of main earner in the household, no. of people sleeping per room, season, country, and method of data collection. Consistent with a study in China [4], those who lived in the rural setting were 1.5 times more likely to experience AGI than those who lived in the urban settings, which is in contrast with another study in China [5]. Individuals in a household with working or student main earners had a higher prevalence of AGI than those in a household where the main earner was a housewife, consistent with studies in Cuba and Chile. In one of the study countries (i.e., Nigeria), individuals in a household with the fourth- and highest-level assets were four times more likely to experience AGI than those with second- and middle-level assets, which is consistent with studies in China and Barbados. Overall, this thesis (Chapter 2) revealed that the epidemiology of AGI in the four African LMICs of this study corresponds to those reported from studies in other LMICs.

The self-evaluation of our project's collaboration, management, and implementation process (Chapter 3) highlighted that our partnership formation considered the interplay and

balance between operations and relations. One feature of the partnership was focus on shared goals and aims, where the partners also identified gaps that require improvement. The research team elucidated slight working culture differences of the intercontinental collaboration. This thesis (Chapter 3) identified trust and commitment as the core values, which the team evaluated by signifying the need to build more on enhancing responsibility-sharing and dedication. This thesis assessed the partnership as inclusive, including gender sensitivity; however, they recognized the need to be vigilant in handling inputs from partners and ensuring the inclusiveness of their decisions. Each team member has acknowledged the mutual benefits of taking part in the survey, with the need to ensure that every team member is well-acquainted with mutual benefits.

This thesis also illustrated the communication features of the team member's interaction (openness, transparency, honesty, and unambiguity) while showing the existing communication gaps and their intentions to improve on various components. The team unanimously agreed that the leadership attributes (and their dependent resolution strategies) they expounded on worked well, and they acknowledge the need to keep with these same attributes and strategies in their remaining activities. In general, this thesis (Chapter 3) demonstrated that, through the partnership and research, successful partnerships need to consider these core concepts explicitly, apply the essential leadership attributes, perform situational analysis before designing the research, and expect differences in work culture. Moreover, experiences like this can help inform other similar surveys, for example, those studying the burden of foodborne or related diseases in African or other LMICs.

The application of foodborne underreporting adjustment methods to COVID-19 for Toronto, Canada (Chapter 4) revealed that 1 in 18 COVID-19 infections that occurred in the

community was reported to Toronto Public Health, which is higher than those reported in a US study. These numbers interpreted to tens of thousands of COVID-19 infections that occurred in the community during the earlier phase of the pandemic, before lab testing became widely available, and that approximately 5.6% of COVID-19 infections were captured through routine public health disease surveillance during this early pandemic phase (March-May 2020). The under-ascertainment approach yielded slightly higher estimates than those reported in a COVID-19 seroprevalence study for Ontario during the same timeframe, though the differences were not significant. The approach in this thesis allowed identification of where cases were lost in the reporting chain. To conclude, the COVID-19 pandemic provided an opportunity to apply the under-ascertainment measurement approach used for foodborne infections to COVID-19. Thus, this thesis (Chapter 4) demonstrated that the method is useful for other infectious diseases under public health surveillance.

Contributions to the AGI literature

This thesis includes the first estimates of the epidemiology of AGI at the population level in the African LMICs, which included respondents from the urban and rural settings of each study country (Chapter 2). Furthermore, the thesis applied an internationally comparable case definition [6], that allowed comparison with studies of other LMICs [4,5,7–13] and high-income countries (Table A1 in Appendix A). The application of two recall periods (2-week and 4-week), and the DHS case definition of diarrhea [14–17], on the estimation of AGI allowed comparison with each study country's DHS estimates and the bulk of studies available in the study countries and other African LMICs [18–26]. Also, as has been done by other AGI studies [4,5,7,8,10–13,27–36] (see Table A1 in Appendix A), this thesis (Chapter 2) employed a retrospective, cross-sectional population survey using a face-to-face interview data collection method that allowed comparison.

This thesis also used a web survey by distributing an anonymous survey link, making about one-third of the survey respondents. The dual methods of data collection in this thesis allowed comparison of data collection methods and put forth the lessons learned in the African settings (Chapter 3), including technical challenges of implementing a web-based data collection system related to infrastructure (such as limited internet and technology access) as well as varying levels of literacy in such similar settings. This thesis (Chapter 2) identified the significant public health burden of AGI in the study communities of Ethiopia, Mozambique, Nigeria, and Tanzania, as demonstrated by a comparable (with other LMICs) annual incidence rate that was less than one episode of AGI per person-year.

This thesis identified that majority of the AGI cases in the study had diarrhea, with the most common additional symptoms including abdominal pain, stomach pain, fever, headache, and nausea, which is comparable with other similar studies in other LMICs [10–13,31,36]. Chapter 2 also showed slightly greater severity of AGI, which indicated that the consequences of AGI could be more devastating in these study populations than others. The thesis (Chapter 2) found that about a quarter of AGI cases had someone else in the household with AGI, which could strengthen the fact that the presence of a sick individual(s) in the household could facilitate the spread of AGI by a person to person transmission [37].

Sick individuals might not visit health facilities to receive health care for AGI [38], and of the people who did, only some might be asked for a stool sample. Even if a stool sample was requested, some individuals still could fail to submit a sample to a laboratory. Lastly, some laboratory results might not be recorded [1–3,38–40]. This thesis (Chapter 2) demonstrated that only about one-third of those with AGI did not seek medical care, and of those, only one-twentieth were requested to submit a stool sample. This finding could confirm that epidemiological

surveillance of AGI can capture the AGI burden on the segment of the community who seek medical care [39,40], and this thesis provided information that would help to estimate the underreporting and under-ascertainment rate of AGI in the health surveillance system in the study countries.

This thesis used year-based data that allowed to measure AGI occurrence across seasons in each country. However, there was no observed significant difference across the dry and wet season in this thesis, as opposed to the fact that the occurrence of AGI varies according to the time of the year, which is categorized into seasons of a year [41–43].

Demographic determinants are population characteristics that can influence the occurrence of AGI [44–46]. This thesis (Chapter 2) showed an agreement with findings from other studies [4,5,8,9,11,12] concerning the higher prevalence of AGI among children aged less than five years compared to adults. Chapter 2 revealed that those who lived in the rural settings were more likely to experience AGI than those who lived in the urban settings. Here, the higher AGI prevalence in the rural population could be due to low access to safe and adequate water supply, and also low level of awareness of hygienic practices [47]. The household wealth status could influence the occurrence of AGI [48], and this thesis identified that those individuals in a household with the higher-level assets were more likely to experience AGI than those with average-level assets. This thesis also identified that individuals in a household with working or student main earners had a higher prevalence of AGI than those in a household where the main earner was a housewife, which is consistent with other studies in Cuba and Chile [5,49]. AGI prevalence could vary across different occupations of the household's main earner due to the difference in the related economic activities and the consequent perception of symptoms to report the illness [5,49].

The data collected in this thesis, specifically among the items measuring the wealth index (such as access to drinking water, sanitary facilities, housing conditions, livestock ownership, and fuel for cooking), could be further analyzed to help evaluate potential exposure factors for AGI. Examining the association of the source of drinking water (piped/protected versus unprotected) and the type of toilet (flushed/ ventilated pit latrine versus no slab pit latrine/open field) with the presence of AGI could help identify potential exposures as indicated by previous studies [9,10,29,47,50–52]. Public health personnel could use such information to target and design cost-effective/affordable strategies that help improve the drinking water and toilet-related problems in the respective communities - depending on the existence of an association. The prevalence of AGI could vary by housing conditions: floor material (i.e., wood/ceramic/cement versus earth/sand/dung); wall material (i.e., wood/metal/cement versus grass/thatch/mud); or roof material (i.e., iron sheet/cement versus grass/thatch/mud) [51,52]. Such information is useful to public health personnel to target interventions such as searching for cost-effective/affordable technologies that help improve the housing conditions in the communities for the variables that showed significant association(s).

The association between livestock ownership, as a potential exposure variable, and the presence of AGI could be explored by using data collected in this thesis as indicated by other studies [9,12,29,47,51]. The outcome could help target interventions that aim to control AGI, for example, by targeting intervention actions towards promoting hygiene of animals, reducing contact with animals, and separating living spaces for animals. The use of dung for fuel for cooking could be examined for its association with AGI as a potential exposure variable as indicated by a study in Asian LMIC [51]. The promotion of the use of other affordable sources of fuel for cooking in

the communities could be among the public health measure to put in place when there are more cases of AGI among those who use dung as a source of fuel for cooking.

Moreover, among the items added later during survey implementation to examine the influence of the pandemic on the thesis outcome, those assessing self-reported hand/food hygiene practices could also be further explored for their association with AGI. As indicated by previous studies [10,29,47,51], hand hygiene practices, including the frequency, timing, and use of detergents/sanitizers, could be explored for a potential association with the presence of AGI. Examining such associations could help identify links in the AGI transmission chain and target interventions such as promoting hand hygiene at crucial times (including after using the toilet and before eating food) and the use of affordable detergents. The type (fully cooked versus under-cooked/raw foods) and handling practices (washing fresh vegetables/fruits before consumption versus not washing) of foods could be explored for a potential association with the presence of AGI, as reported by other studies [12,53]. Public health personnel could use such information to help target interventions that promote eating of fully cooked foods and thoroughly cleaning of fresh vegetables/fruits before consumption. In summary, this thesis identified that in Ethiopia, Mozambique, Nigeria, and Tanzania, AGI appears to pose a considerable incidence that suggests regular surveillance and intervention are needed.

Chapter 3 demonstrated that the driving force that helped the multi-national study team move forward in the collaboration establishment process was a mix of operations and relationships. Partners came together for the research project in part via pre-existing connections [54]. The designing of the population survey (Chapter 2) was preceded by setting shared goals and aims (here, estimating the epidemiology of AGI in the respective African countries) as suggested by Leone Sciabolazza et al. [55]. This thesis (Chapter 3) revealed that there could be

instances of a lack of timely execution of specific tasks, even when there is an agreed timeline at a team level. While operating together, this thesis (Chapter 3) identified slight variations in work culture, which, as noted by Gélinas [56], is to be expected as research partners could come from multiple countries/institutions. Situations where these variations were noticeable included inconsistencies in reacting time on action points, sharing accountability on overdue or undone tasks, timeliness on notifying changes or challenges, voluntarily taking leads on extra responsibilities and delegation of duties.

This thesis (Chapter 3) evaluated that the partnership was inclusive as a recommended practice for collaborative research [57,58]. This inclusiveness was possible since the collaborators have been jointly engaged in almost every decision made from the formation stage, and each partner appropriately contributed to the work. This thesis (Chapter 3) also exhibited that starting from the partnership formation stage, as proposed by papers on collaborative research [54,58], the research team strived to encourage mutual benefits among partners. Corresponding to the recommended practice, the research team aspired to build the partnership with open and transparent communications, via multiple platforms, among partners [56,59].

Chapter 3 noted instances where the partners failed to: give feedback urging timely actions/changes; execute decision/action points promptly; attend one-on-one meetings; communicate survey progresses, updates, challenges, or general comments on time; and actively contribute to group conversations. According to Morrison-Smith & Ruiz [60], given the challenge with quality interaction in geographically dispersed study teams, hierarchical leadership is not the best approach, and empowering the team members is key. This thesis identified that hierarchical positionality or power imbalance has not been noticeable in the collaboration, which is also linked with the full and equitable delegation of tasks. Regardless,

this thesis (Chapter 3) identified different levels of performances among partners in terms of time and efficiency. The study team also foresaw short- and long-term research outputs akin to other collaborative efforts [56].

Chapter 3 also suggests best practices (including the leading role of experts with experience in similar surveys, smooth working relationship with institutional and other stakeholders, active cooperation with local community/religious leaders, and mobilization of trained health extension workers /community health workers) and identifies challenges (including challenges of implementing a web survey related to infrastructure, inputting characters of one language to Qualtrics, people speaking other than survey languages in some countries, a cumbersome and time-consuming ethics approval process, difficulty to access sampled households, and participants' expectations for support/incentives). In general, future population surveys or other collaborative studies of the burden of infectious diseases in African or other LMICs may benefit from partnerships that consider the interplay and balance between operations and relations and leadership attributes (and their dependent resolution strategies). These attributes include full and equitable delegation of tasks that eliminated hierarchical positionality and the flexibility to alter premade decisions and execute action points.

This thesis (Chapter 4) explored the applicability of methods typically used to adjust for under-reporting of foodborne and AGI infections to COVID-19. This stochastic modelling (Chapter 4) of the fraction of COVID-19 cases captured at each step in the reporting chain to estimate the under-ascertainment of COVID-19 in Toronto allowed accounting for the uncertainty about the actual values of the proportions reported at the steps in the reporting chain, using available data sources. Chapter 4 revealed that, during the first wave of the COVID-19 pandemic, only a fraction of the total COVID-19 cases occurring in the community was reported to Toronto

Public Health, with an estimated 18 infections occurring in the community for each COVID-19 case reported to the local public health unit. This under-ascertainment rate is higher than the estimate from the US [61]. This thesis showed that the method used for foodborne and AGI infections and influenza [1–3], yielded slightly higher estimates than those reported in a COVID-19 seroprevalence study for Ontario during the same timeframe [62], but the differences were not significant. To conclude, the COVID-19 pandemic provided an opportunity to apply the under-ascertainment measurement approach used for foodborne infections to COVID-19 and demonstrated its importance (Chapter 4).

Implications for public health practice

This thesis provided evidence about the epidemiology of AGI in Ethiopia, Mozambique, Nigeria, and Tanzania that can help inform the respective public health officials in decision-making related to the prevention and reduction of AGI in the study countries and other African LMICs. Specifically, the incidence estimates can be used to estimate and compare the burden of AGI and inform prioritization by the public health officials/personnel, while the demographic determinants of AGI help to target and allocate resources to the more affected/vulnerable population sub-group. The estimates can also contribute to global-level estimates, including systematic reviews or meta-analyses. The findings from this thesis will form the basis to estimate the etiological fractions of AGI caused by foodborne pathogens. Moreover, it has improved our knowledge regarding the number of cases captured by the health care surveillance system, thereby forming the basis for the design of surveillance of AGI. This thesis also presented a lesson informative for any future collaborative effort in the public health sphere targeting the measure and reduction of the burden of AGI in African LMICs. This lesson encompassed the necessary core concepts, steps, actions, leadership attributes, and foreseeable challenges in collaborative

research on AGI in the African setting. This thesis demonstrated that public health personnel or research could apply the under-ascertainment measurement approach used for foodborne infections and influenza to other infectious diseases under public health surveillance such as COVID-19. Moreover, as reported numbers do not reflect the actual infection rate in the community, policymakers, program planners, and local public health units could use the ratio of reported versus potentially missed cases in such infectious disease outbreaks.

Limitations

As described in other similar studies elsewhere [4,12,29,63,64], I identified limitations that arose from this population survey of AGI. The generalizability of the findings to the within-country population needs to be approached cautiously, given the multi-ethnicity or multi-cultural groups available in the countries, as opposed to selecting two study sites considering urban or rural status. Nonetheless, given the anticipated possibility of a mixed aggregate of multiple ethnic populations in the study areas, the weighting of sample estimates using the available recent census data likely allowed to have more representative results.

Upon analyzing data from all countries, the prevalence of AGI varied between the web and face-to-face survey participants. After adjusting for other demographic variables (age, gender, wealth index, residence, employment status of the main earner in the household, and the number of people sleeping per room, season, and country) in the multivariable model, the respondents to the web survey had a higher likelihood of developing AGI than the respondents to the face-to-face survey. The higher odds of AGI cases among the web survey than the face-to-face participants could (1) indicate that the method of data collection variable is a potential confounder and (2) be due to a potential selection bias. This bias could have occurred as respondents who chose to complete a web survey could be those who experienced the AGI symptoms, or those who

experienced AGI might refuse to reveal their symptoms to an interviewer. As the aim of this thesis was to determine the association between demographic factors and the presence of AGI, including the method of data collection variable in the multivariable modelling allowed accounting for its confounding effect in examining the association. Historically, similar studies of AGI employed an interview technique (e.g., face-to-face or telephone) and indicated that some respondents could prefer not to disclose their AGI symptoms to an interviewer [4,5,7,8,10–13,27–36]. Thus, future studies should explore and compare findings and limitations via employing dual or more data collection methods.

The estimation of AGI occurrence in this study relied on self-reports of AGI symptoms/occurrence, as the scope of this study did not encompass laboratory confirmation. AGI in this study relied on an internationally suggested case definition, which allowed comparison and would inform decision-making by responsible government bodies in the respective countries. Biases such as recall bias, interviewer bias, and misclassification bias are expected from studies using self-reported case definitions. The bias minimizing strategies included training data collectors on survey tools and interviewing skills, allowing optimum time of data collection for both the web survey and face-to-face data collection, and setting skip logics/patterns that assist in reducing mistyping.

Directions for future research

Such population-level epidemiologic studies need to be done regularly to address the possible population changes concerning age-gender-urban/rural status distribution, lifestyle, and incidents like the COVID-19 pandemic. Like the study countries in this thesis and others, every other African LMICs need to conduct a population-level study aimed to estimate the epidemiology of AGI. Studies would be more informative if planned for a duration that allows

seasonal comparison, like other studies, before the COVID-19 pandemic, found AGI to vary across seasons. Applying a standard case definition allows the comparison of the estimates produced from AGI studies. Studies on the pathogenic agents of AGI at the population level are also needed to characterize the etiological proportion of AGI and help target prevention measures. Studies to determine the underreporting and under-ascertainment rate of AGI in the existing surveillance system are needed, and this applies to the pathogen-specific AGI proportions. More studies are also needed to verify the applicability of the under-ascertainment measurement approach for foodborne infections and influenza to other infectious diseases.

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Appendices

Appendix A: Additional Tables – Chapter 1

Table A1. Findings of diarrheal or AGI studies in high-income countries, based on publications since 2004

Country	Method	Incidence (episodes per person-year)	Prevalence (Monthly in percentage)	Average duration (in days)	Authors and year
Norway	Population survey (Mail based self-administered)	1.2	9.3	5	(Kuusi et al., 2003)
Canada	Population survey (Telephone)	1.3	10.04	4	(Majowicz et al., 2004)
Ireland	Population survey (Telephone)	0.60	NR	NR	(Scallan et al., 2004)
USA	Population survey (Telephone)	0.72	6	2 (median)	(Imhoff et al., 2004)
Australia	Population survey (Telephone)	0.83	6.4	NR	(Scallan et al., 2005)
Canada		0.99	7.6	NR	
Ireland		0.44	3.4	NR	
USA		0.99	7.6	NR	
Australia	Population survey (Telephone)	0.92	7.4	NR	(Hall et al., 2006)
Canada (British Columbia)	Population survey (Telephone)	1.3	9.2	3.7	(Thomas et al., 2006)
USA	Population survey (Telephone)	0.6	5.1	3	(Jones et al., 2007)

Malta	Population survey (Telephone)	0.421	3.18	6.8	(Gauci et al., 2007)
Canada (Ontario)	Population survey (Telephone)	1.17	8.56	4	(Sargeant et al., 2008)
USA	Population survey (Telephone)	0.9	7.7	NR	(Cantwell et al., 2010)
USA (Georgia)	Population survey (Telephone)	0.41	NR	NR	(Hall et al., 2011)
New Zealand	Population survey (Telephone)	1.11	8.6	2.5	(Adlam et al., 2011)
Denmark	Population survey (Telephone)	1.4	10.7	3	(Müller, Korsgaard, & Ethelberg, 2012)
Italy	Population survey (Telephone)	1.08	8.9	3.22	(Scavia, Baldinelli, Busani, & Caprioli, 2012)
Poland	Population survey (Telephone)	0.9	6.7	NR	(Baumann-Popczyk et al., 2012)
UK	Prospective cohort	0.274	NR	NR	(Tam et al., 2012)
Netherlands	Population survey (Mail based self-administered)	0.96	7.4	2 (median)	(Doorduyn et al., 2012)
France	Population survey (Telephone)	0.33	NR	2.9	(Van Cauteren et al., 2012)

Germany	Population survey (Telephone)	0.95	7.5	3.8	(Wilking et al., 2013)
Sweden	Population survey (Mail based self-administered)	0.31	NR	3 (median)	(Hansdotter et al., 2015)
Canada (Rigolet and Iqaluit)	Population survey (Face-to-face)	3.0-3.1	14.8-17.1	NR	(Harper et al., 2015)
Sweden	Population based cohort	0.36	NR	3.4	(Edelstein, Merk, Deogan, Carnahan, & Wallensten, 2016)
UK	Population survey (Telephone)	0.533	NR	NR	(Viviani et al., 2016)
England		0.449	NR	NR	
Northern Ireland		0.802	NR	NR	
Scotland		1.196	NR	NR	
Wales		0.662	NR	NR	
Canada	Population survey (Telephone)	0.77	5.7	2.6	(Thomas et al., 2017)

NR – Not Reported

Table A2**.** Two-week prevalence of diarrhea among children below the age of five years from Demographic Health Surveys in Ethiopia, Mozambique, Nigeria, and Tanzania

Country	**Prevalence (%)**	**Report and year**
Ethiopia	12	(Ethiopian DHS, 2016)
Mozambique	11	(Mozambique DHS, 2019)
Nigeria	10	(Nigerian DHS, 2014)
Tanzania	12	(Tanzanian DHS, 2016)

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Appendix B: Additional Tables – Chapter 2

Table B1. Summary of details about each of the study sites of a cross-sectional survey of acute gastrointestinal illness in Ethiopia, Mozambique, Nigeria, and Tanzania, October 2020 – September 2021

	Ethiopia		**Mozambique**		**Nigeria**		**Tanzania**	
	Urban (Harar)	**Rural** (Kersa)	**Urban** (Polana Caniço - KaMaxaque)	**Rural** (Marracuene)	**Urban** (Abeokuta, Ogun State)	**Rural** (Ofada/ Mokoloki, Local Council Development Area, Ogun State)	**Urban** (Moshi Municipal)	**Rural** (Moshi Rural)
Population of the study site	99,321	172,626	199,565	230,530	~446,088	Unknown	184,292	466,737
Initial target sample size	372	372	984	984	552	552	432	408
Revised target sample size, post-pilot	372	372	552	552	552	552	432	408
Final no. surveys completed	411	384	429	500	722	759	744	551

Format of survey administration		Web-survey, Face-to-face	Web-survey, Face-to-face	Web-survey, Face-to-face	Web-survey, Face-to-face	Web-survey, Face-to-face	Face-to-face only	Web-survey, Face-to-face	Web-survey, Face-to-face
Initial start date of data collection*		March 11, 2020		March 18, 2020		February 21, 2020		February 17, 2020	
Survey languages		Amharic, Afaan Oromoo		Portuguese		Yoruba, English		Kiswahili	
Ethical review boards	Local	Institutional Health Research Ethics Review Committee (IHRERC) of Haramaya University (#Not provided); National Research Ethics Committee (#MoSHE//RD/14.2/9849/12)		The National Bioethical committee, Ministry of Health (#CIBS FM&HCM/092/2019)		Federal Medical Centres (#NHREC/08/10-2015); State Health Service Commission (#02/10/19/041); State Hospital Management Board (#SHH/EC/EA/03/07/20)		Kilimanjaro Christian Medical Centre (KCMC) (#2446); National Institute of Medical Research (NIMR) (#NIMR/HQ/R.8a/Vol. IX/3273)	
	International	A University of Waterloo Research Ethics Committee (ORE #40458; Canada)							

Age of assent to participate, and to complete the survey themselves (years)	14-17	12-17	14-17	14-17
Remuneration	None	1USD per online survey completion	None	1USD per online survey completion

*Data collection paused for all on March 26, 2020, and all countries collected data from October 01, 2020, to September 30, 2020.

Table B2. Wealth variables collected in a cross-sectional survey of acute gastrointestinal illness, assigned to where they are likely to be found, wealthier versus poorer, Ethiopia, Mozambique, Nigeria, and Tanzania, October 2020 – September 2021

Variable	**Wealthier**	**Poorer**
Source of drinking water	1 = Piped into dwelling/yard or communal tap or neighbors' home or protected well/spring or water from rain or tanker/trunk or bottled/sachet water	0 = Unprotected well/spring or surface-river, lake, dam
Type of toilet	1 = Flushed to piped sewer system or flush to septic tank or Ventilated-Improved-Pit latrine or pit latrine with slab or unshared facility	0 = Pit latrine with no slab or no latrine/open field or shared facility
Floor material	1 = Rudimentary wood plank, adobe, polished wood, ceramic tile/brick, cement	0 = earth, sand, or dung
Wall material	1 = Masica stick or casca or wood or metal planks or adobe or brick or cement block	0 = No walls or grass/thatch/mud or tin/cardboard/paper
Roof material	1 = Iron sheet or calamine/cement fiber or tile or cement/concrete	0 = No roof or grass/thatch/mud
Fuel for cooking	1 = Electricity or kerosene or cooking gas	0 = Coal/lignite or charcoal or firewood or dung
Has an electric supply	1 = Yes	0 = No
Has a TV	1 = Yes	0 = No
Has a radio	1 = Yes	0 = No

Has a refrigerator (functional)	1 = Yes	0 = No
Has a bicycle	1 = Yes	0 = No
Has a motor bicycle/scooter	1 = Yes	0 = No
Has a car/ truck	1 = Yes	0 = No
Has an animal-drawn cart	1 = Yes	0 = No
Has a boat with motor	1 = Yes	0 = No
Has a mobile phone	1 = Yes	0 = No
Has a watch	1 = Yes	0 = No
Number of people sleeping per room	1 = Five or fewer	0 = Six or more people
Own an agriculturally usable land	1 = Yes	0 = No
Have cows/bulls	1 = Yes	0 = No
Have horses/ donkeys/ mules	1 = Yes	0 = No
Have goats	1 = Yes	0 = No
Have sheep	1 = Yes	0 = No
Have chickens	1 = Yes	0 = No
Have ducks	1 = Yes	0 = No
Have pigeons	1 = Yes	0 = No
Have pigs	1 = Yes	0 = No

Have a bank account/ or belong to a savings or micro-credit group	1 = Yes	0 = No
Own a house	1 = Yes	0 = No
Own a land	1 = Yes	0 = No

Appendix C. Population Survey Tool, as formatted for Qualtrics

Start of Block: Age Category

PLEASE CHANGE THE LANGUAGE TO YOUR LOCAL LANGUAGE TO COMPLETE THE SURVEY BY USING THE LANGUAGE DROPDOWN MENU ABOVE
Population Survey (Diarrheal Disease in Ethiopia, Mozambique, Nigeria, Tanzania)

PLEASE BE ADVISED THAT YOU HAVE TO BE 18 YEARS OR OLDER TO ANSWER THIS SURVEY.

QLoctn Please pick your location of resident

- HARAR CITY, ETHIOPIA
- KERSA, ETHIOPIA
- POLANA CANICO (KAMAXAQUE), MOZAMBIQUE
- MARRACUENE, MOZAMBIQUE
- ABEOKUTA, OGUN STATE, NIGERIA
- OFADA/MOKOLOKI, LCDA, OGUN STATE, NIGERIA
- MOSHI MUNICIPAL, TANZANIA
- MOSHI RURAL, TANZANIA

QCommVDc Please tell us who you are?

- A COMMUNITY MEMBER
- A FOCAL DATA COLLECTOR

Skip To: AGE If Please tell us who you are? != A FOCAL DATA COLLECTOR

Display This Question:
If Please tell us who you are? = A FOCAL DATA COLLECTOR

*

QDCinitials If you are a FOCAL data collector, please give us your initials

_____

AGE Please tell us for whom you are answering the survey? As we have a separate survey form for different age groups:

YOURSELF (18 YEARS OLD AND ABOVE)

YOUR CHILD OR DEPENDENT (LESS THAN 18 YEARS OLD)

End of Block: Age Category

Start of Block: Adult Consent

AdultConsent PARTICIPANT INFORMATION SHEET AND CONSENT - ADULT We are conducting a survey to determine how many people, of all ages, get sick with diarrheal disease in <<INSERT COUNTRY: Ethiopia/ Mozambique/ Nigeria/ Tanzania>>, as well as in <<INSERT OTHER THREE COUNTRIES>>. In <<COUNTRY>>, this study is being conducted in partnership by the Technical University of Denmark, the University of Waterloo, Canada, and <<NAME OF REGIONAL COLLABORATING INSTITUTION(S)>>, and it is co-funded by the Bill and Melinda Gates Foundation and Foreign, Commonwealth & Development Office (FCDO) of the United Kingdom Government and led by the Technical University of Denmark (Lead Investigator: Dr. Tine Hald).

Randomly or self-selected people like you in your community of <<PLACE NAME>> is being invited to participate in this survey. Participating is voluntary, and your identity will be kept confidential. As part of the <<PLACE NAME>> community, there is no direct harm or benefit by participation in the study. However, your participation is extremely valuable, since it may allow public health and other programs to better prevent diarrhea disease in <<COUNTRY>>, as these illnesses continue to be a concern, even during the current COVID 19 pandemic. We will be able to see how the risk changes over time, including as wider factors like the COVID-19 pandemic change. The data you provide will be combined with information from many other people in your community, and this information will be shared through a controlled-access to our team of researchers, from around the world, who are working together on the issue of diarrheal diseases.

In this survey, we will ask you some questions about your health, specifically about stomach and intestinal illness, as well as some general demographic questions. The questions will take about 15 – 20 minutes, and you may skip questions or stop the survey at any point along the way. This study has been reviewed and cleared by the [LOCAL INSTITUTES' RESEARCH ETHICS BOARD] and the University of Waterloo, Research Ethics Committee (file number# 40458). If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact: [CONTACT ADDRESS OF THE LOCAL INSTITUTES' RESEARCH ETHICS OFFICE] or email to the University of Waterloo, Office of Research Ethics (ore-ceo@uwaterloo.ca). By providing your consent, you are not waiving your legal rights

or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

QAdultConsent Do you consent to participate in this study?

YES

NO

Skip To: End of Survey If Do you consent to participate in this study? != YES

End of Block: Adult Consent

Start of Block: Demography Questions Adult

PREVIOUS SURVEY PARTICIPATION AND SOCIO-DEMOGRAPHY CHARACTERISTICS OF HOUSEHOLD

Q1 Have you answered this survey before?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q4 If Have you answered this survey before? != YES

Display This Question:
If Have you answered this survey before? = YES

Q2 When did you answer the survey before?

THIS PAST WEEK

THIS PAST MONTH

SEVERAL MONTHS AGO

ABOUT A YEAR AGO

OVER A YEAR AGO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Have you answered this survey before? = YES

Q3 Were you having diarrhea that time you have participated in this survey?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q4 What is the employment status of the main earner in the household?

WORKING

RETIRED

STUDENT

HOUSEWIFE

DISABLED

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please Specify) _____

Q5 What is the average monthly income (in USD) of the main earner in the household?

ENTER NUMBER _____

⊗DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

WATER AND SANITATION CONDITIONS

Q6 What is your source of drinking water? Select all that apply:

PIPED INTO DWELLING

PIPED INTO YARD

COMMUNAL TAP

NEIGHBOR'S HOUSE

PROTECTED WELL

UNPROTECTED WELL

PROTECTED SPRING

UNPROTECTED SPRING

SURFACE WATER-RIVER, LAKE, DAM

WATER FROM RAIN

WATER FROM TANKER TRUNK

BOTTLED WATER

SACHET WATER

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q7 What type of toilet are you using? Select all that apply:

FLUSH TO PIPED SEWER SYSTEM

FLUSH TO SEPTIC TANK

VIP LATRINE

PIT LATRINE WITH SLAB

PIT LATRINE WITH NO SLAB

⊗NO LATRINE FACILITY/ OPEN FIELD

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Skip To: Q9 If What type of toilet are you using? Select all that apply: = NO LATRINE FACILITY/ OPEN FIELD
Skip To: Q9 If What type of toilet are you using? Select all that apply: = DON'T KNOW/ NOT SURE
Skip To: Q9 If What type of toilet are you using? Select all that apply: = PREFER NOT TO RESPOND

Q8 If you have a toilet, do you share facilities with other household members?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q9 What sewage disposal means or treatment system are you on?

COMMUNAL TREATMENT PLANT

LOCAL TREATMENT PLANT

SEPTIC TANK

TRADITIONAL PIT

NO TREATMENT PLANT

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please specify) _____

HOUSING CONDITIONS

Q10 What is the floor material of your house? Select all that apply:

EARTH, SAND OR DUNG

RUDIMENTARY WOOD PLANK

ADOBE

POLISHED WOOD

CERAMIC TILE/ BRICK

CEMENT

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q11 What is the wall material of your house? Select all that apply:

NO WALLS

GRASS/ THATCH/ MUD

TIN/ CARDBOARD/ PAPER/ BAGS

MASICA STICKS

CASCA

WOOD OR METAL PLANKS

ADOBE

BRICK

CEMENT BLOCK

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q12 What is the roof material of your house? Select all that apply:

NO ROOF

GRASS/ THATCH/ MUD

IRON SHEET

CALAMINE/ CEMENT FIBER

TILE

CEMENT (CONCRETE)

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q13 What type of fuel does your household use for cooking? Select all that apply:

ELECTRICITY

KEROSENE

COAL/ LIGNITE

CHARCOAL

FIREWOOD

DUNG

COOKING GAS

⊗DOES NOT COOK

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q14 Does your household have an electric supply?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q15 Does your household have a television?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q16 Does your household have a radio?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q17 Does your household have a refrigerator (functional)?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q18 Which type of vehicle does any member of your household have/own? Select all that apply:

BICYCLE

MOTOR BICYCLE/ SCOOTER

CAR/ TRUCK

ANIMAL-DRAWN CART

BOAT WITH MOTOR

⊗DON'T HAVE ANY

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q19 Does anyone in your household have a mobile phone?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q20 If Does anyone in your household have a mobile phone? != YES

Display This Question:
If Does anyone in your household have a mobile phone? = YES

Q19b Who is the primary user of the phone? Select all that apply:

ALL ADULT MEMBERS

MALE, HEAD OF HOUSEHOLD/ HUSBAND

FEMALE, HEAD OF HOUSEHOLD/ WIFE

YOUNG ADULT(S) IN THE HOUSE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q20 Does anyone in your family have a watch?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q21 The number of people sleeping per room?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q22 Does your household own agriculturally-usable land (located anywhere)?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q24 If Does your household own agriculturally-usable land (located anywhere)? != YES

Display This Question:

If Does your household own agriculturally-usable land (located anywhere)? = YES

Q23 Hectares of agricultural land owned?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q24 Which livestock does your household own? Select all that apply:

COWS/ BULLS

HORSES/ DONKEYS/ MULES

GOATS

SHEEP

CHICKENS

DUCKS

PIGEONS

PIGS

⊗NONE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q25 Do anyone in your household have a bank account/ or belong to a savings or micro-credit group?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q26 Does your household own a house?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q27 Does your household own land?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q28 What is your area of residence?

URBAN

SEMI-URBAN

RURAL

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

QUESTIONS ADDRESSING THE CHANGES DUE TO COVID 19 PANDEMIC

---

cvQ1 Have you been washing your hands by applying any detergent/disinfectant solution with rubbing hands together for 20 seconds?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: cvQ5 If Have you been washing your hands by applying any detergent/disinfectant solution with rubbing han... != YES

cvQ2 How many times (on average) do you wash/sanitize your hands per day within the last two weeks?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ3 When do you think is the appropriate time for handwashing/ sanitizing? *Please select all that apply*

AFTER TOUCHING DOOR HANDLES, TABLES/CHAIRS, CUPBOARD METAL, PLASTIC ITEMS

BEFORE PREPARING FOOD

BEFORE FEEDING CHILDREN

AFTER FEEDING CHILDREN

AFTER VISITING TOILET

BEFORE TOUCHING GARBAGE

BEFORE CHANGING INFANT NAPPIES

AFTER CHANGING INFANT NAPPIES

BEFORE VISITING TOILET

AFTER HELPING CHILDREN'S DEFECATION

OTHER (Please Specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ4 What did you use to wash/rub your hands within the last two weeks? Please select all that apply

WATER ONLY

SOAP AND WATER

ALCOHOL-BASED SANITIZER

OTHER (Please Specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ5 During the past two weeks, how frequently did your family cook food or meals from basic ingredients? (e.g. eggs, raw meat, raw vegetables, flour, salt, yeast, water)

MORE THAN TWICE A DAY

AT LEAST ONCE A DAY

A FEW TIMES IN A WEEK

A FEW TIMES IN THE TWO WEEKS

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ6 Within the last two weeks, how frequently did your family cook food or meals using ingredients such as ginger, lemon and pepper as per the government suggestions to combat COVID-19?

MORE THAN TWICE A DAY

AT LEAST ONCE A DAY

A FEW TIMES IN A WEEK

A FEW TIMES IN THE TWO WEEKS

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ7 Have you consumed any of the following raw or under-cooked meals (except vegetables and fruits) within the last two weeks? *Please select all that apply*

RAW/ UNDER-COOKED BEEF/GOAT MEAT

RAW/ UNDER-COOKED FISH MEAT

RAW/ UNDER-COOKED POULTRY MEAT

RAW/ UNDER-COOKED PORK MEAT

RAW MILK

OTHER (Please Specify) _____

⊗NOT CONSUMED ANY

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ8 How often did your family wash any fresh fruits and vegetables you consumed within the last two weeks?

EVERY TIME

MOST OF THE TIME

SOMETIMES

RARELY

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: cvQ10 If How often did your family wash any fresh fruits and vegetables you consumed within the last two w... = NEVER
Skip To: cvQ10 If How often did your family wash any fresh fruits and vegetables you consumed within the last two w... = DON'T KNOW/ NOT SURE
Skip To: cvQ10 If How often did your family wash any fresh fruits and vegetables you consumed within the last two w... = PREFER NOT TO RESPOND

cvQ9 What did your family use to wash the fresh fruits and vegetables you consumed within the last two weeks? Please select all that apply

SOAP

HOT WATER

COOL RUNNING WATER

OTHER (Please Specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ10 Within the last two weeks, when did you (your family members) wash, rinse, and sanitize kitchen counters? Please select all that apply

BEFORE EACH USE

AFTER EACH USE

WHEN YOU BEGIN WORKING WITH ANOTHER TYPE OF FOOD

AT REGULAR (E.G. 4-HOUR) INTERVALS IF THE COUNTER IS IN CONSTANT USE

ONCE IN A DAY

ONCE IN THE TWO WEEKS

⊗NOT WASHED/SANITIZED

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ11 During the past two weeks, how frequently did your family sanitize the kitchen sink drain in your home?

DAILY

EVERY OTHER DAY

WEEKLY

ONCE IN THE TWO WEEKS

NOT SANITIZED

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

End of Block: Demography Questions Adult

Start of Block: Diarrhea - Adult

DIARRHEAL DISEASE AND RELATED QUESTIONS - ADULTS

Q29 What is your gender?

MALE

FEMALE

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q30 What is your age? (in years)

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Please pick your location of resident != HARAR CITY, ETHIOPIA
And Please pick your location of resident != KERSA, ETHIOPIA

Q31 Which ethnic group do you belong to?

Ethnicity 1

Ethnicity 2

Ethnicity 3

Ethnicity 4

Ethnicity 5

Ethnicity 6

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q32 Within the past 4 weeks, were you ill with vomiting or diarrhea?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q60 If Within the past 4 weeks, were you ill with vomiting or diarrhea? != YES

Q33 Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7 days in between illnesses)

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q36 If Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7... != YES
Skip To: Q34 If Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7... = YES

Display This Question:
If Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7... = YES

Q34 If you were sick more than once in the past 4 weeks, how many times were you sick?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7... = YES

Q35 If you were sick more than once, then when did your most recent illness start? (Please answer all questions below for your most recent illness - by illness we mean the finite period in which you are affected by the illness)

TAKE ME TO THE CALENDAR

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q36 If If you were sick more than once, then when did your most recent illness start? (Please answer all... != TAKE ME TO THE CALENDAR

Display This Question:
If If you were sick more than once, then when did your most recent illness start? (Please answer all... = TAKE ME TO THE CALENDAR

JS

Q35Date If you were sick more than once, then when did your most recent illness start? (*Please answer all questions below for your **most recent illness** - by illness we mean the finite period in which you are affected by the illness*)

_____

Display This Question:
If Within the past 4 weeks, were you sick more than once? (Where you had no symptoms for at least 7... != YES

Q36 When did your illness start?

TAKE ME TO THE CALENDAR

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q37 If When did your illness start? != TAKE ME TO THE CALENDAR

Display This Question:
If When did your illness start? = TAKE ME TO THE CALENDAR

JS

Q36Date When did your illness start?

_____

Q37 During your illness, did you have any diarrhea? (*By diarrhea we mean any loose stool or stool with abnormal liquidity*)

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q40 If During your illness, did you have any diarrhea? (By diarrhea we mean any loose stool or stool wi... != YES

Display This Question:
If During your illness, did you have any diarrhea? (By diarrhea we mean any loose stool or stool wi... = YES

Q38 Was there ever any blood in your stool?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If During your illness, did you have any diarrhea? (By diarrhea we mean any loose stool or stool wi... = YES

Q39 On your worst day, what was the most number of times you had loose stools?

ENTER NUMBER _____

CONSTANT/ ALL DAY LONG

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q40 During your illness, did you have any vomiting?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q42 If During your illness, did you have any vomiting? != YES

Display This Question:
If During your illness, did you have any vomiting? = YES

Q41 On your worst day, what was the most number of times you vomited?

ENTER NUMBER _____

CONSTANT/ ALL DAY LONG

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q42 What other symptoms did you have? Select all that apply:

STOMACH CRAMPS

ABDOMINAL PAIN

FEVER

CHILLS

HEADACHE

NAUSEA

MUSCLE / BODY ACHES

SORE THROAT

COUGHING

SNEEZING

RUNNY NOSE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q43 Considering all your symptoms, are you still sick?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q44 How many days have you been sick for?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q45 Considering all your symptoms, how long did your illness last?

LESS THAN A DAY

ONE OR MORE DAYS (ENTER NUMBER)

_____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q46 Have you ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's disease, ulcerative colitis, cystic fibrosis, or coeliac disease?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q48 If Have you ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's disease,... != YES

Display This Question:

If Have you ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's disease,... = YES

Q47 Do you think your illness (diarrhea and vomiting) was due to these diseases which you have been diagnosed for?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q48 Do you think your illness was due to any of the following? Select all that apply:

OTHER CHRONIC OR LONG-LASTING ILLNESS

MEDICATION OR MEDICAL ILLNESS

INFECTIOUS DISEASES SUCH AS MALARIA, BRUCELLOSIS, ETC.

FOOD CONSUMPTION

PREGNANCY OR MORNING ILLNESS

ALCOHOL OR DRUG USE

⊗NONE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q49 Did you seek care for medical advice or treatment of these symptoms?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q58 If Did you seek care for medical advice or treatment of these symptoms? != YES

Display This Question:
If Did you seek care for medical advice or treatment of these symptoms? = YES

Q50 Which of the following health care provider(s) did you consult with? Select all that apply:

GENERAL PRACTITIONER

PRIVATE CLINIC

AFTER-HOURS DOCTOR

HOSPITAL EMERGENCY DEPARTMENT

HEALTH CENTER

NURSING SERVICES

PHARMACIST

HEALTHLINE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

ALTERNATIVE HEALTHCARE

Skip To: Q52 If Which of the following health care provider(s) did you consult with? Select all that apply: != PREFER NOT TO RESPOND

Display This Question:
If Which of the following health care provider(s) did you consult with? Select all that apply: = ALTERNATIVE HEALTHCARE

Q51 Please specify the type of the alternative healthcare? Select all that apply:

NATUROPATHY

HOMEOPATHY

CHIROPRACTICS

HERBALIST

OTHER (Please specify) _____

Display This Question:
If Did you seek care for medical advice or treatment of these symptoms? = YES

Q52 Were you admitted to hospital overnight for this illness?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Did you seek care for medical advice or treatment of these symptoms? = YES

Q53 As a result of this illness, were you asked to provide a stool sample for testing by a laboratory?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If As a result of this illness, were you asked to provide a stool sample for testing by a laboratory? = YES

Q54 Did you provide the requested stool sample?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q57 If Did you provide the requested stool sample? != YES

Display This Question:
If Did you provide the requested stool sample? = YES

Q55 Do you know the result of the stool sample testing?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q58 If Do you know the result of the stool sample testing? != YES

Display This Question:
If Do you know the result of the stool sample testing? = YES

Q56 What was the result?

4 _____

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Did you provide the requested stool sample? = NO

Q57 Why did you not provide a stool sample? Select all that apply:

RECOVERED / FELT BETTER

INCONVENIENCE (TIME, LACK OF FACILITIES)

DISGUSTING / UNPLEASANT

PHYSICALLY UNABLE

UNABLE/ UNWILLING TO PAY FOR THE TEST

FORGOT

⊗DON'T KNOW / NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q58 Did you take any medication for your symptoms?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q60 If Did you take any medication for your symptoms? != YES

Display This Question:
If Did you take any medication for your symptoms? = YES

Q59 Did you take any of the following medications? Select all that apply:

MEDICINE TO STOP DIARRHEA (E.G. IMMODIUM, LOMOTIL)

MEDICINE TO STOP NAUSEA (E.G. MAXALON, STEMETIL)

ANTIBIOTICS (E.G. AMOXIL, SYNERMOX, ERYTHROMYCIN, BACTRIM)

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q60 Of the people in your household, how many others had diarrhea or vomiting within the past 4 weeks?

NONE

1 OR MORE (ENTER NUMBER)

_____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

End of Block: Diarrhea - Adult

Start of Block: Child Parent Consent

PGConsent PARTICIPANT INFORMATION SHEET AND CONSENT – CHILD'S PARENT/GUARDIAN We are conducting a survey to determine how many people, of all ages, get sick with diarrheal disease in <<INSERT COUNTRY: Ethiopia/ Mozambique/ Nigeria/ Tanzania>>, as well as in <<INSERT OTHER THREE COUNTRIES>>. In <<COUNTRY>>, this study is being conducted in partnership by the Technical University of Denmark, the University of Waterloo, Canada, and <<NAME OF REGIONAL COLLABORATING INSTITUTION(S)>>, and it is co-funded by the Bill and Melinda Gates Foundation and Foreign,

Commonwealth & Development Office (FCDO) of the United Kingdom Government and led by the Technical University of Denmark (Lead Investigator: Dr. Tine Hald).

Randomly or self-selected children like yours in your community of <<PLACE NAME>> is being invited to participate in this survey. Participating is voluntary, and your or your child's identity will be kept confidential. As part of the <<PLACE NAME>> community, there is no direct harm or benefit by participation in the study. However, your participation is extremely valuable, since it may allow public health and other programs to better prevent diarrhea disease in <<COUNTRY>>, as these illnesses continue to be a concern, even during the current COVID 19 pandemic. We will be able to see how the risk changes over time, including as wider factors like the COVID-19 pandemic change. We will share the data you/ your child provide through a controlled-access to other researchers from around the world.

We would like to ask you some questions about your child's health specifically about stomach and intestinal illness, as well as some general demographic questions. There is no direct harm or benefit by participation in the study, but your child's participation (<18 years old) in this study is extremely valuable, since it will allow us to better target prevention and other public health programs. The questions will take about 15 - 20 minutes & questions may be skipped or the survey ended at any point along the way. If you want to answer the questions for your child you may, or he/she can complete the survey directly during which you are welcome to monitor the survey completion. This study has been reviewed and cleared by the [LOCAL INSTITUTES' RESEARCH ETHICS BOARD] and the University of Waterloo, Research Ethics Committee (file number# 40458). If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact: [CONTACT ADDRESS OF THE LOCAL INSTITUTES' RESEARCH ETHICS OFFICE] or email to the University of Waterloo, Office of Research Ethics (ore-ceo@uwaterloo.ca). By providing your consent, you are not waiving your or your child's legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

QPGConsent Do you consent participation of your child in this study?

YES

NO

Skip To: End of Survey If Do you consent participation of your child in this study? != YES
Skip To: QChildAge If Do you consent participation of your child in this study? = YES

QChildAge How old is your child?

LESS THAN 14 YEARS

14 TO 17 YEARS (PLEASE LET YOUR CHILD GIVE CONSENT)

End of Block: Child Parent Consent

Start of Block: Demography Questions Child

PREVIOUS SURVEY PARTICIPATION AND SOCIO-DEMOGRAPHY CHARACTERISTICS OF HOUSEHOLD

Q61 Have you answered this survey for this child before?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q4C If Have you answered this survey for this child before? != YES

Display This Question:
If Have you answered this survey for this child before? = YES

Q62 When did you answer the survey before?

THIS PAST WEEK

THIS PAST MONTH

SEVERAL MONTHS AGO

ABOUT A YEAR AGO

OVER A YEAR AGO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Have you answered this survey for this child before? = YES

Q63 Was your child having diarrhea the time you completed this survey on his/her behalf?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q4C What is the employment status of the main earner in the household?

WORKING

RETIRED

STUDENT

HOUSEWIFE

DISABLED

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q5C What is the average monthly income (in USD) of the main earner in the household?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

WATER AND SANITATION CONDITIONS

Q6C What is your source of drinking water? Select all that apply:

- PIPED INTO DWELLING
- PIPED INTO YARD
- COMMUNAL TAP
- NEIGHBOR'S HOUSE
- PROTECTED WELL
- UNPROTECTED WELL
- PROTECTED SPRING
- UNPROTECTED SPRING
- SURFACE WATER-RIVER, LAKE, DAM
- WATER FROM RAIN
- WATER FROM TANKER TRUNK
- BOTTLED WATER
- SACHET WATER
- ⊗DON'T KNOW/ NOT SURE
- ⊗PREFER NOT TO RESPOND
- OTHER (Please specify) _____

Q7C What type of toilet are you using? Select all that apply:

FLUSH TO PIPED SEWER SYSTEM

FLUSH TO SEPTIC TANK

VIP LATRINE

PIT LATRINE WITH SLAB

PIT LATRINE WITH NO SLAB

⊗NO LATRINE FACILITY/ OPEN FIELD

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Skip To: Q9C If What type of toilet are you using? Select all that apply: = NO LATRINE FACILITY/ OPEN FIELD
Skip To: Q9C If What type of toilet are you using? Select all that apply: = DON'T KNOW/ NOT SURE
Skip To: Q9C If What type of toilet are you using? Select all that apply: = PREFER NOT TO RESPOND

Q8C If you have a toilet, do you share toilet facilities with other household members?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q9C What sewage disposal means or treatment system are you on?

COMMUNAL TREATMENT PLANT

LOCAL TREATMENT PLANT

SEPTIC TANK

TRADITIONAL PIT

NO TREATMENT PLANT

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please specify) _____

HOUSING CONDITIONS

Q10C What is the floor material of your house? Select all that apply:

EARTH, SAND OR DUNG

RUDIMENTARY WOOD PLANK

ADOBE

POLISHED WOOD

CERAMIC TILE/ BRICK

CEMENT

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q11C What is the wall material of your house? Select all that apply:

NO WALLS

GRASS/ THATCH/ MUD

TIN/ CARDBOARD/ PAPER/ BAGS

MASICA STICKS

CASCA

WOOD OR METAL PLANKS

ADOBE

BRICK

CEMENT BLOCK

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q12C What is the roof material of your house? Select all that apply:

NO ROOF

GRASS/ THATCH MUD

IRON SHEET

CALAMINE/ CEMENT FIBER

TILE

CEMENT (CONCRETE)

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q13C What type of fuel does your household use for cooking? Select all that apply:

ELECTRICITY

KEROSENE

COAL/ LIGNITE

CHARCOAL

FIRE WOOD

DUNG

COOKING GAS

⊗DOES NOT COOK

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q14C Does your household have an electric supply?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q15C Does your household have a television?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q16C Does your household have a radio?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q17C Does your household have a refrigerator (functional)?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q18C Which type of vehicle does any member of your household have/own? Select all that apply:

BICYCLE

MOTOR BICYCLE/ SCOOTER

CAR/ TRUCK

ANIMAL-DRAWN CART

BOAT WITH MOTOR

⊗DON'T HAVE ANY

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q19C Does anyone in your household have a mobile phone?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q20C If Does anyone in your household have a mobile phone? != YES

Display This Question:
If Does anyone in your household have a mobile phone? = YES

Q19bC Who is the primary user of the phone? Select all that apply:

ALL ADULT MEMBERS

MALE, HEAD OF HOUSEHOLD/ HUSBAND

FEMALE, HEAD OF HOUSEHOLD/ WIFE

YOUNG ADULT(S) IN THE HOUSE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q20C Does anyone in your family have a watch?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q21C The number of people sleeping per room?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q22C Does your household own agriculturally-usable land (located anywhere)?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q24C If Does your household own agriculturally-usable land (located anywhere)? != YES

Display This Question:

If Does your household own agriculturally-usable land (located anywhere)? = YES

Q23C Hectares of agricultural land owned?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q24C Which livestock does your household own? Select all that apply:

COWS/ BULLS

HORSES/ DONKEYS/ MULES

GOATS

SHEEP

CHICKENS

DUCKS

PIGEONS

PIGS

⊗NONE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q25C Do anyone in your household have a bank account/ or belong to a savings or micro-credit group?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q26C Does your household own a house?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q27C Does your household own land?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q28C What is your area of residence?

URBAN

SEMI-URBAN

RURAL

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

QUESTIONS ADDRESSING THE CHANGES DUE TO COVID 19 PANDEMIC

---

cvQ1c Have your child (you) been cleaning his/her (your child’s) hands by applying any detergent/disinfectant solution with rubbing hands together for 20 seconds?

YES

NO

DON’T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: cvQ6c If Have your child (you) been cleaning his/her (your child’s) hands by applying any detergent/disinf... != YES

cvQ2c How many times (on average) did your child (you) wash/sanitize his/her (your child's) hands per day within the last two weeks?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ3c For the past two weeks, how often did you wash your hands before feeding your child?

AT ALL TIMES

NOT EVERYTIME

NOT AT ALL

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ4c When is the appropriate time for handwashing/ sanitizing? *Please select all that apply.*

AFTER TOUCHING DOOR HANDLES, TABLES/CHAIRS, CUPBOARD, METAL, PLASTIC ITEMS

BEFORE PREPARING FOOD

BEFORE FEEDING CHILDREN

AFTER FEEDING CHILDREN

AFTER VISITING TOILET

BEFORE TOUCHING GARBAGE

BEFORE CHANGING INFANT NAPPIES

AFTER CHANGING INFANT NAPPIES

BEFORE VISITING TOILET

AFTER HELPING CHILDREN'S DEFECATION

OTHER (Please specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ5c What did your child (or you) use to wash/rub his/her (your child's) hands within the last two weeks? *Please select all that apply.*

WATER ONLY

SOAP AND WATER

ALCOHOL-BASED SANITIZER

OTHER (Please specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ6c During the past two weeks, how frequently did your family cook food or meals from basic ingredients? (e.g. eggs, raw meat, raw vegetables, flour, salt, yeast, water)

MORE THAN TWICE A DAY

AT LEAST ONCE A DAY

A FEW TIMES IN A WEEK

A FEW TIMES IN THE TWO WEEKS

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ7c Within the last two weeks, how frequently did your family cook food or meals using ingredients such as ginger, lemon and pepper as per the government suggestions to combat COVID-19?

MORE THAN TWICE A DAY

AT LEAST ONCE A DAY

A FEW TIMES IN A WEEK

A FEW TIMES IN THE TWO WEEKS

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

---

cvQ8c Did your child consume any of the following raw or under-cooked meals (except vegetables and fruits) within the last two weeks? *Please select all that apply*

RAW/ UNDER-COOKED BEEF/GOAT MEAT

RAW/ UNDER-COOKED FISH MEAT

RAW/ UNDER-COOKED POULTRY MEAT

RAW/ UNDER-COOKED PORK MEAT

RAW MILK

OTHER (Please Specify) _____

⊗NOT CONSUMED ANY

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ9c How often did your family wash any fresh fruits and vegetables your child consumed within the last two weeks?

EVERY TIME

MOST OF THE TIME

SOMETIMES

RARELY

NEVER

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: cvQ11c If How often did your family wash any fresh fruits and vegetables your child consumed within the las... = NEVER
Skip To: cvQ11c If How often did your family wash any fresh fruits and vegetables your child consumed within the las... = DON'T KNOW/ NOT SURE
Skip To: cvQ11c If How often did your family wash any fresh fruits and vegetables your child consumed within the las... = PREFER NOT TO RESPOND

cvQ10c What did your family use to wash the fresh fruits and vegetables that your child consumed within the last two weeks? *Please select all that apply*

SOAP

HOT WATER

COOL RUNNING WATER

OTHER (Please Specify) _____

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ11c Within the last two weeks, how often did your family wash, rinse, and sanitize kitchen counters? *Please select all that apply*

BEFORE EACH USE

AFTER EACH USE

WHEN YOU BEGIN WORKING WITH ANOTHER TYPE OF FOOD

AT 4-HOUR INTERVALS IF THE COUNTER IS IN CONSTANT USE

ONCE IN A DAY

ONCE IN THE TWO WEEKS

⊗NOT WASHED/SANITIZED

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

---

cvQ12c During the past two weeks, how frequently did your family sanitize the kitchen sink drain in your home?

DAILY

EVERY OTHER DAY

WEEKLY

ONCE IN THE TWO WEEKS

NOT SANITIZED

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

End of Block: Demography Questions Child

Start of Block: Diarrhea - Child

CHILD'S DIARRHEAL DISEASE AND RELATED QUESTIONS

Q64 What is your child's gender?

MALE

FEMALE

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q65 What is your child's age?

ENTER NUMBER (months old) _____

ENTER NUMBER (years old) _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Please pick your location of resident != HARAR CITY, ETHIOPIA
And Please pick your location of resident != KERSA, ETHIOPIA

Q66 Which ethnic group does your child belong to?

ETHNICITY 1

ETHNICITY 2

ETHNICITY 3

ETHNICITY 4

ETHNICITY 5

ETHNICITY 6

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q67 Within the past 4 weeks, was your child ill with vomiting or diarrhea?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q95 If Within the past 4 weeks, was your child ill with vomiting or diarrhea? != YES
Skip To: Q68 If Within the past 4 weeks, was your child ill with vomiting or diarrhea? = YES

Q68 Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms for at least 7 days in between illnesses)

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q71 If Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms fo... != YES
Skip To: Q69 If Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms fo... = YES

Display This Question:
If Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms fo... = YES

Q69 If your child was sick more than once, how many times?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms fo... = YES

Q70 If your child was sick more than once, when did your child's most recent illness start? (Please answer all questions below for your most recent illness - by illness we mean the finite period in which you are affected by the illness)

TAKE ME TO THE CALENDAR

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q71 If If your child was sick more than once, when did your child's most recent illness start? (Please a... != TAKE ME TO THE CALENDAR

Display This Question:
If If your child was sick more than once, when did your child's most recent illness start? (Please a... = TAKE ME TO THE CALENDAR

JS

Q70Date If your child was sick more than once, when did your child's most recent illness start? (*Please answer all questions below for your **most recent illness** - by illness we mean the finite period in which you are affected by the illness***)**

_____

Display This Question:
If Within the past 4 weeks, was your child sick more than once? (Where your child had no symptoms fo... != YES

Q71 When did your child's illness start?

TAKE ME TO THE CALENDAR

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q72 If When did your child's illness start? != TAKE ME TO THE CALENDAR

Display This Question:
If When did your child's illness start? = TAKE ME TO THE CALENDAR

JS

Q71Date When did your child's illness start?

_____

Q72 During your child's illness, did your child have any diarrhea? (*By diarrhea we mean any loose stool*)

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q75 If During your child's illness, did your child have any diarrhea? (By diarrhea we mean any loose sto... != YES

Display This Question:
If During your child's illness, did your child have any diarrhea? (By diarrhea we mean any loose sto... = YES

Q73 Was there ever any blood in your child's stool?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If During your child's illness, did your child have any diarrhea? (By diarrhea we mean any loose sto... = YES

Q74 On your child's worst day, what was the most number of times your child had loose stools?

ENTER NUMBER _____

CONSTANT/ ALL DAY LONG

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q75 During your child's illness, did your child have any vomiting?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q77 If During your child's illness, did your child have any vomiting? != YES

Display This Question:
If During your child's illness, did your child have any vomiting? = YES

Q76 On your child's worst day, what was the most number of times your child vomited?
ENTER NUMBER _____

CONSTANT/ ALL DAY LONG

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q77 What other symptoms did your child have? Select all that apply:
STOMACH CRAMPS

ABDOMINAL PAIN

FEVER

CHILLS

HEADACHE

NAUSEA

MUSCLE / BODY ACHES

SORE THROAT

COUGHING

SNEEZING

RUNNY NOSE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q78 Considering all your child's symptoms, is your child still sick?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q79 How many days has your child been sick for?

ENTER NUMBER _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q80 Considering all your child's symptoms, how long did your child's illness last?

LESS THAN A DAY

ONE OR MORE DAYS (ENTER NUMBER)

_____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q81 Has your child ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's disease, ulcerative colitis, cystic fibrosis, or coeliac disease?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q83 If Has your child ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's di... != YES

Display This Question:

If Has your child ever been diagnosed with cancer of the bowel, irritable bowel syndrome, Crohn's di... = YES

Q82 Do you think your child's illness (diarrhea or vomiting) was due to that?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Q83 Do you think your child's illness was due to any of the following? Select all that apply:

OTHER CHRONIC OR LONG-LASTING ILLNESS

MEDICATION OR MEDICAL ILLNESS

INFECTIOUS DISEASES SUCH AS MALARIA, BRUCELLOSIS, ETC.

FOOD CONSUMPTION

PREGNANCY OR MORNING ILLNESS

ALCOHOL OR DRUG USE

⊗NONE

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q84 Did you seek care for your child with medical advice or treatment of these symptoms?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q93 If Did you seek care for your child with medical advice or treatment of these symptoms? != YES

Display This Question:

If Did you seek care for your child with medical advice or treatment of these symptoms? = YES

Q85 Which of the following health care providers did your child consult with? Select all that apply:

GENERAL PRACTITIONER

PRIVATE CLINIC

AFTER-HOURS DOCTOR

HOSPITAL EMERGENCY DEPARTMENT

HEALTH CENTER

NURSING SERVICES

PHARMACIST

HEALTHLINE (24-HOUR TELEPHONE HEALTH ADVICE)

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

ALTERNATIVE HEALTHCARE

Skip To: Q87 If Which of the following health care providers did your child consult with? Select all that apply: != ALTERNATIVE HEALTHCARE

Display This Question:
If Which of the following health care providers did your child consult with? Select all that apply: = ALTERNATIVE HEALTHCARE

Q86 Please specify the type of alternative healthcare? Select all that apply:

NATUROPATHY

HOMEOPATHY

CHIROPRACTICS

HERBALIST

OTHER (Please specify) _____

Display This Question:
If Did you seek care for your child with medical advice or treatment of these symptoms? = YES

Q87 Was your child admitted to the hospital overnight for this illness?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Did you seek care for your child with medical advice or treatment of these symptoms? = YES

Q88 As a result of this illness, was your child asked to provide a stool sample for testing by a laboratory?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q93 If As a result of this illness, was your child asked to provide a stool sample for testing by a labo... != YES

Display This Question:
If As a result of this illness, was your child asked to provide a stool sample for testing by a labo... = YES

Q89 Did your child provide the requested stool sample?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q92 If Did your child provide the requested stool sample? != YES

Display This Question:
If Did your child provide the requested stool sample? = YES

Q90 Do you know the result of the stool sample test?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q93 If Do you know the result of the stool sample test? != YES

Display This Question:
If Do you know the result of the stool sample test? = YES

Q91 What was the result?

4 _____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Display This Question:
If Did your child provide the requested stool sample? = NO

Q92 Why did your child not provide a stool sample? Select all that apply:

RECOVERED / FELT BETTER

INCONVENIENCE (TIME, LACK OF FACILITIES)

DISGUSTING / UNPLEASANT

PHYSICALLY UNABLE

UNABLE/ UNWILLING TO PAY FOR THE TEST

FORGOT

⊗DON'T KNOW / NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q93 Did your child take any medication for his/her symptoms?

YES

NO

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

Skip To: Q95 If Did your child take any medication for his/her symptoms? != YES

Display This Question:
If Did your child take any medication for his/her symptoms? = YES

Q94 Did your child take any of the following medications? Select all that apply:

MEDICINE TO STOP DIARRHEA (E.G. IMMODIUM, LOMOTIL)

MEDICINE TO STOP NAUSEA (E.G. MAXALON, STEMETIL)

ANTIBIOTICS (E.G. AMOXIL, SYNERMOX, ERYTHROMYCIN, BACTRIM)

⊗DON'T KNOW/ NOT SURE

⊗PREFER NOT TO RESPOND

OTHER (Please specify) _____

Q95 Of the people in your household, how many others had diarrhea or vomiting within the past 4 weeks?

NONE

1 OR MORE (ENTER NUMBER)

_____

DON'T KNOW/ NOT SURE

PREFER NOT TO RESPOND

End of Block: Diarrhea - Child

Start of Block: Teenager Assent

ChildAssent PARTICIPANT INFORMATION SHEET AND ASSENT – CHILD Your parents should allow you to come to this page and participate in this project. This questionnaire looks at how many people, of all ages, get sick with diarrheal disease in your country.

As far as we know, being in this study will not hurt you, and it will not make you feel bad. What we find in this study will help the effort of reducing diarrheal disease suffering among children and adults, as these illnesses continue to be a concern, even during the current COVID 19 pandemic. You do not have to be in the study. No one will get angry or upset with you if you do

not want to do this. Your answers will not have your name with it, so no one will know they are your answers. We want you to respond freely, and no one will see your answers, even your parents. The researchers will not let anyone other than themselves see your answers or any other information about you. We will carefully share the information you give, which will not identify you, to other researchers from around the world.

If you decide to take part in this study, we will ask you some questions about your health, specifically about stomach sickness, as well as specific questions about you. When you answer the questions, try your best or say I do not know. If you do not want to answer, you are not supposed to as you always have a choice to skip. Answering all the questions will take you about 15 to 20 minutes.

QChildAssent Do you consent to participate in this study?

YES

NO

Skip To: End of Survey If Do you consent to participate in this study? != YES
Skip To: QChildPref If Do you consent to participate in this study? = YES

QChildPref Do you want your parents/guardians to respond on your behalf?

YES (MY PARENTS/GUARDIANS WILL COMPLETE THE SURVEY)

NO (I WANT TO COMPLETE THE SURVEY BY MYSELF)

End of Block: Teenager Assent

Appendix D. Formulae Used for Incidence and Prevalence Calculations – Chapter 2

I. Formulae to adjust for the 4-week incidence rate

$$\frac{[\text{Average Duration of Illness } - 1]}{[28 + (\text{Average Duration of Illness } - 1)]}$$

II. Formulae to calculate the incidence and prevalence

Annual incidence rate

(4-week recall)

$$= \frac{Incident\ cases}{\frac{1}{2}[(Total\ population\ at\ risk) + (Total\ population\ at\ risk - Incident\ cases)]} * \frac{365}{28}$$

Annual incidence proportion

(4-week recall)

$$= 1 - (1 - x)^{365/28}$$

Where, x represents number of incident cases divided by total population at risk.

Period prevalence

(4-week recall)

$$= \frac{Number\ of\ cases\ in\ the\ 28\ days\ of\ recall}{Total\ population\ at\ risk}$$

(2-week recall)

$$= \frac{Number\ of\ cases\ in\ the\ 14\ days\ of\ recall}{Total\ population\ at\ risk}$$

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Appendix E: Sensitivity Analysis – Chapter 4

We conducted a sensitivity analysis to assess the influence of our assumptions and analytic decisions on the under-ascertainment estimates from our main analysis via fourteen scenarios, by comparing the percent change in the under-ascertainment multiplier under different scenarios. The impacts of the twelve modelling decisions/assumptions are shown in Table E1. Overall, the differences made by including scenarios listed in Table E1 were negligible. The first scenario that showed the highest deviation from our under-ascertainment mean estimate was for the proportion of those who sought care that got tested when using a beta distribution where the denominator and numerators values were derived solely from the population survey. The other scenario that showed the second-highest deviation from our under-ascertainment mean estimate was the proportion of those with COVID-19 in the community who were symptomatic, replaced with the smallest proportion (23%) from studies in the literature.

Table E1. Sensitivity analysis illustrating the estimated COVID-19 under-ascertainment multiplier in Toronto, Ontario, March to May, 2020, under different modeling decisions and assumptions

Scenario	**Multiplier for the Entire Time Period**	**Multiplier by Testing Window**		
		1st	**2nd**	**3rd**
		Up to March 12, 2020	**March 13 to April 9, 2020**	**April 10 to May 23, 2020**
MAIN RESULTS, REPEATED FROM TABLE 2	18.395	28.001	19.846	13.879
REPORTED CASE DATA				
The number of cases reported determined using reported and specimen collection date combined	18.359	23.675	17.193	13.926
The number of cases reported determined using specimen collection date only	18.547	23.907	17.450	14.635
WEEKLY TESTING DATA				
The two suppressed cell counts replaced as one and five and included in the number of positive tests	18.443	30.114	19.835	13.889
The two suppressed cell counts replaced as five and five and included in the number of positive tests	18.345	31.305	19.766	13.836
The two suppressed cell counts replaced as three and three and included in the number of positive tests	18.443	30.114	19.835	13.889

The two suppressed cell counts replaced as one and one and included in the number of positive tests	18.477	28.670	19.875	13.870
TEST SENSITIVITY				
The minimum test sensitivity value replaced to be 38%, and included in the proportion of those who sought testing that tested positive	24.394	37.495	26.353	18.454
POPULATION SURVEY				
For the proportion of those who sought care that got tested, using a beta distribution where the denominator and numerators were values derived from the population survey	72.626	108.394	80.453	43.513
For the proportion of those who sought care that got tested, replacing the maximum value as 90% for the pert distribution	18.513	28.386	19.912	14.020
For the proportion of those who sought care that got tested, replacing the maximum value as 95% for the pert distribution	18.432	28.389	19.913	13.961
Individuals who sought care via Ontario's online COVID-19 self-assessment tool included in the number who sought testing	10.476	16.687	11.653	7.764
Individuals who fulfilled any of the criteria in the three windows included to the proportion **of** those with COVID symptoms who met the testing criteria, regardless of the time they met the criteria (Individuals with non-sensical dates, n=371)	23.429	N/A*	N/A	N/A

SYMPTOMATIC PROPORTION				
For the proportion of those with COVID-19 in the community who were symptomatic, replacing to the smallest proportion (23%) from studies in the literature	66.449	101.220	70.924	49.857
For the proportion of those with COVID-19 in the community who were symptomatic, replacing to the highest proportion (80%) from studies in the literature	23.034	35.268	24.676	17.417

*N/A – Not Applicable

Appendix F: Additional Tables – Chapter 4

Table F1. Data completeness by variable for the COVID-19 population survey (n=3,529), Toronto, Ontario, Canada, March to May, 2020

Variable	**Number missing (%)**
Symptomatic Status	1227 (34.77)
Symptomatic respondents (n=1444)	
Gender	132 (9.14)
Age	122 (8.45)
Onset Date	361 (25.00)
Resolved Date	817 (56.58)
Testing for COVID-19	317 (22.00)
Care seeking	317 (22.00)
Chronic illnesses or underlying medical conditions	317 (22.00)

Table F2. Data matched with testing windows for the three data sets (COVID-19 population survey, weekly testing, and reported case data) in Toronto, Ontario, Canada, March to May, 2020

Number of Responses / Data Points, by Data Source	Entire Time Period	By Testing Window		
		1st	2nd	3rd
		Up to March 12, 2020	March 13 to April 9, 2020	April 10 to May 23, 2020
REPORTED CASE DATA (n=5530 symptomatic and confirmed cases) *				
TOTAL NO. REPORTED CASES (USING REPORTED DATE) INCLUDED IN THE ANALYSIS FOR EACH TIME PERIOD	5530	57	1341	4132
WEEKLY TESTING DATA**				
For the 17 weeks falling completely within the testing window, the number positive	6178	16	1215	4947
For testing week March 8 to 14, the number positive divided proportionally by 5 days in the 1st window, 2 days in the 2nd window	99	71	28	
For testing week April 5 to 11, the number positive divided proportionally by 5 days in the 2nd window, 2 days in the 3rd window	652		466	186
TOTAL NO. POSITIVES INCLUDED IN THE ANALYSIS FOR EACH TIME PERIOD	6929	87	1709	5133

POPULATION SURVEY DATA (n=1433 symptomatic respondents) ***				
Those with both onset and resolved dates reported (606/1433; 42.29%)				
Onset and resolved dates both falling within a single window	340	28	279	33
Onset date in the 1st, and resolved date in the 2nd, window	154		154	
Onset date in the 1st, and resolved date in the 3rd, window	30			30
Onset date in the 2nd, and resolved date in the 3rd, window	81			81
Onset date in the 3rd, and resolved date after the 3rd, window	1			1
Those with onset dates only (456/1433; 31.82%)	456	50	327	79
TOTAL NO. SURVEY RESPONDENTS INCLUDED IN THE ANALYSIS FOR EACH TIME PERIOD	1062	262	871	224

*****Span of reported date: January 23, 2020 - May 23, 2020.
******Start date of the first week: January 12, 2020; End date of the last week: May 23, 2020.
***Span of onset date: September 27, 2019 - May 30, 2020; Span of resolved date: January 2, 2020 - June 5, 2020.

Table F3. Studies from high income countries on asymptomatic proportion of COVID-19 cases, January to November, 2020

Author(s) & Year	Country	Study population (Population type, sampling, age)	Study period	Sample size (Tested)	Total number tested positive for COVID-19 (%)	Asymptomatic proportion (95% CI)
Surveillance report						
Spiterl et al., 2020 (Spiteri et al., 2020)	WHO European Region	Surveillance report from health facilities (general population – all ages)	January to February 2020	NR	31	0.065 (NR)
Toronto Public Health	Canada	All cases	January 1 – May 23, 2020	NA	10517 (NA)	0.154 (NA)
Toronto Public Health	Canada	All cases	January 1, 2020 – July 26, 2021	NA	151243 (NA)	0.174 (NA)
Toronto Public Health	Canada	Confirmed cases only	January 1 – May 23, 2020	9701	9701 (100)	0.166 (NA)
Toronto Public Health	Canada	Confirmed cases only	January 1, 2020 – July 26, 2021	147155	147155 (100)	0.175 (NA)
Toronto Public Health	Canada	Sporadic cases only	January 1 – May 23, 2020	NA	6025 (NA)	0.081 (NA)

Toronto Public Health	Canada	Sporadic cases only	January 1, 2020 – July 26, 2021	NA	131277 (NA)	0.150 (NA)
Toronto Public Health	Canada	Outbreak associated cases	January 1 – May 23, 2020	NA	4492 (NA)	0.254 (NA)
Toronto Public Health	Canada	Outbreak associated cases	January 1, 2020 – July 26, 2021	NA	19966 (NA)	0.174 (NA)
Screening in general population						
Lavezzo et al, 2020 (Lavezzo et al., 2020)	Italy	General population (Longitudinal study – No random sample)	February to March 2020	5155	102 (2.0)	0.425 (0.315, 0.546)
Gudbjartsson et al., 2020 (Gudbjartsson et al., 2020)	Iceland	General population (Random sampling)	March to April, 2020	13080	100 (0.8)	0.430 (NR)
Chamie et al., 2020 (Chamie et al., n.d.)	USA	General population (Longitudinal study – No random sample -≥4 years)	April, 2020	3871	83 (2.1)	0.277 (NR)
Menachemi et al., 2020 (Menachemi et al., 2020)	USA	General population (Random sampling - ≥12 years)	April, 2020	3605	47 (1.7)	0.442 (NR)
Snoeck et al., 2020	Luxemburg	General population	April to May, 2020	1862	5 (0.3)	0.200 (NR)

(Snoeck et al., n.d.)		(Random sample)				
Petersen & Phillips, 2020 (Petersen & Phillips, 2020)	England	General population (Random sample)	April to June, 2020	36,061	115 (0.3)	0.765 (0.677, 0.839)
Riley et al, 2020 (a, b, c) (Riley et al., n.d.)	England	General population (Random sample – 5 years and above)	October to November, 2020	932,072	3029 (0.3)	0.470 (NR)
Screenings in defined population settings						
Lombardi et al., 2020 (Lombardi et al., 2020)	Italy	Screening of defined population: Health care workers other than Nursing homes	February to March 2020	1573	138 (8.8)	0.297 (NR)
Romao et al., 2020 (Romão et al., 2020)	Portugal	Screening of defined population: Health care workers	March, 2020	34	14 (41.2)	0.210 (NR)
Treibel et al., 2020 (Treibel et al., 2020)	UK	Screening of defined population: Health care workers	March to April, 2020	400	44 (11.0)	0.270 (NR)

Ly et al., 2020 (Ly et al., 2020)	France	Screening of defined population: Residents and workers in different accommodation centers (shelters, hotels, and other residences)	March to April, 2020	1691	49 (7.0%)	0.510 (NR)
Lan et al., 2020 (Lan, Suharlim, Kales, & Yang, 2021)	USA	Screening of defined population: Grocery retail workers	May, 2020	104	21 (20.2)	0.760 (NR)

NA – Not applicable

NR – Not reported

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Appendix G: Additional Notes on Data Sources – Chapter 4

Here we present additional details about the data manipulation process we undertook on the Toronto Public Health population survey data. Of the 1444 respondents, while the survey asked about symptoms since March 1, 2020, about 57 (3.9%) people reported onset dates before March 1. Four (2.8%) reported onset dates (one with no resolved date) from March 9 to April 03, 2001, where the reported symptoms include runny nose and sore throat, which are unlikely to last for many years; thus, we corrected the year to 2020 assuming it was a typo. We included 34 (2.4%) respondents who reported the onset date before March 1 since they reported the respective resolved date after March 1. We also included 8 (5.5%) respondents who reported an onset date only before March 1, assuming they could not report a resolved date if the symptoms were ongoing by the time they responded to the survey. We excluded nine (0.6%) people who reported both onset and resolved dates before March 1 and one with a resolved date only since they did not match the survey target (i.e., symptoms since March 1, 2020). We also excluded one respondent with an onset date only, which was after the end date (May 23, 2020) of our analysis window.