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Walden University

College of Health Sciences and Public Policy

This is to certify that the doctoral dissertation by

Amans Ntakarutimana

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the review committee have been made.

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Walden University
2024

Abstract

Spatial-Temporal Variation of Diarrhea and Associated Sociobehavioral Factors Between 2010-2020 in Rwanda

by

Amans Ntakarutimana

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Health

Walden University

May 2024

Abstract

The purpose of the present 3-manuscript set of studies was to characterize the variation of diarrhea and its associated factors between 2010-2020 in Rwanda. Secondary data from the Rwanda Demographic Health Surveys of 2010, 2015, and 2020 were analyzed using descriptive, logistic regression, linear regression, and pairwise comparison analyses. The socioecological model served as the theoretical framework for the studies. Findings for Manuscript 1 did not show a statistically significant variation in diarrhea between 2010-2020 but revealed a statistically significant variation in diarrhea across districts, regions, and urban-rural areas. In Manuscript 2, findings revealed a statistically significant association between diarrhea among children under 5 years old and (a) mothers' education and (b) domestic violence against mothers between 2010-2020. In Mansucript 3, study findings showed (a) a stagnant variation in household hand-washing behaviors, (b) a decline in household water treatment and safe storage, and (c) a slight increase in household sanitation but in any case, statistically unrelated to diarrhea among children under 5 years old between 2010-2020 in Rwanda. Across all studies, findings showed diarrhea risk factors are multilevel and unevenly distributed spatially across districts, regions, and urban-rural areas. Implications for positive social change include design and implementation of area-specific diarrhea control interventions with consideration of coverage and adoption sustainability of decisive safe behaviors. These can lead to a significant reduction of diarrhea among children under 5 years old in Rwanda.

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Dedication

The combination of the characteristics of the journey and the time it took to earn a doctorate degree has been one of my most overwhelming and shaping God-led tasks for my complete brokenness before my true edification and equipping enough to honor Him through the imparted capability to accomplish noble work by faith and trust in Him alone. At the same time, the journey has widely opened my eyes to (a) see the world's needs, (b) rethink my sense of living, (c) update my goals, and (d) establish my legacy. I saw in front of me a multitude of opportunities to serve as an agent of positive social change I could not believe before. I was blessed to get the full support of (a) Abera my family, (b) Bethlehem Lutheran Church through Diane Warwick, Steve & Steph's family, and Dave’s family, (c) Mel & Georgia Duncan's Family, (d) Bryan & Elaine’s Family, (e) Union Gospel Mission Twin Cities, and (f) Focus Beyond School leadership, staff, and students. For all the love and support you have given me, I dedicate this accomplishment to you.

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Table of Contents

Part 1: Overview 1

Introduction 1

Background 8

Overview of the Manuscripts 13

Significance 14

Summary 16

Part 2: Manuscripts 18

Manuscript 1 Title: Spatial-Temporal Variation of Diarrhea Between 2010-2020 in Rwanda 18

Outlet for Manuscript 19

Abstract 20

Introduction 21

Literature Review 21

What Is Known and Research Gap 28

Table 1 Main Policy and Strategic Interventions Since 2010 29

Significance of the Study 31

Purpose of the Study, Research Questions, and Hypotheses 32

Methods 33

Data Collection and the Study Participants 33

Variables 33

Design and Analysis 34

Results 34
Stratified Descriptive Statistics 34
Table 2 Prevalence of Diarrhea Between 2010-2020 Across Communities, Regions, Urban-Rural Areas 36
Figure 1 Prevalence of Diarrhea Between 2010-2020 Across Districts in Rwanda 37
Repeated Measures Analysis (Pairwise Comparisons) 37
Table 3 Variation of Diarrhea Between 2010-2020 38
Logistic Regression 38
Table 4 Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2010 40
Table 5 Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2015 42
Table 6 Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2020 44
Figure 2 Variation of Diarrhea in Space Across Districts and Regions Between 2010-2020 45
Discussion 46
Interpretation 46
Limitations 48
Implications 48
Recommendation 48

Conclusion 49

References 50

Manuscript 2 Title: Influence of Mothers' Social Status on Diarrhea Between 2010-2020 in Rwanda 60

Outlet for Manuscript 61

Abstract 62

Introduction 63

Literature Review 64

Significance of the Study 69

Purpose of the Study, Research Questions, and Hypotheses 70

Methods 71

Data Collection and the Study Participants 71

Variables 71

Design and Analysis 72

Results 72

Descriptive Analysis 73

Table 1 Education Level of Mothers in % Between 2005-2020 74

Table 2 Employment Status of Mothers in % Between 2005-2020 76

Table 3 Prevalence of Domestic Violence Against Mothers in % Between 2005-2020 78

Logistic Regression Analysis 79

Table 4 Influence of Mother's Characteristics on Diarrhea in 2010 80

Table 5 Influence of Mother's Characteristics on Diarrhea in 2015 81
Table 6 Influence of Mother's Characteristics on Diarrhea in 2020 82
Repeated Measures Analysis 82
Table 7 Variation of Mother's Education Level Attained Between 2010-2020..... 84
Table 8 Variation of Mother's Domestic Violence Status Between 2010-2020..... 85
Discussion 86
Interpretation..... 86
Limitations 87
Implications..... 88
Recommendation 88
Conclusion 88
References 90
Manuscript 3 Title: Relationship Between Household Water Sanitation and Hygiene Behaviors and Diarrhea Between 2010-2020 in Rwanda 95
Outlet for Manuscript.....96
Abstract 97
Introduction.....98
Literature Review..... 99
Significance of the Study 102
Purpose of the Study, Research Questions, and Hypotheses 104

Methods.....105
Data Collection and the Study Participants 105
Variables 105
Design and Analysis 106
Results.....106
Descriptive Analysis 106
Table 1 Prevalence of Household WASH Behaviors Between 2010-2020..... 107
Pairwise Comparisons..... 108
Table 2 Effect of Time on Household WASH Behaviors Between 2010-2020..... 108
Table 3 Variation of Household WASH Behaviors in Time Between 2010-2020..... 109
Linear Regression 110
Table 4 Relationship Between Diarrhea and Household WASH Behaviors Between 2010-2020 110
Discussion.....111
Interpretation..... 111
Limitations 112
Implications..... 112
Recommendation 112
Conclusion 113
References.....114

Part 3: Summary 121

Integrated Study Findings 121

Potential Social Change and Areas of Future Research 122

Conclusion 123

Consolidated References 124

Part 1: Overview

Introduction

A comprehensive systematic review of 61 selected reports and articles from 2005 to 2020 on diarrhea among children under 5 years old showed that childhood diarrhea (a) constitutes a burden on the health system and families due to economic costs it imposes; (b) can lead to malnutrition, stunting, and delayed brain growth later in life due to its repeated episodes; and (c) can compromise the wellbeing of households due to stress and tension it causes to the affected households (Hutton & Chase, 2017; Manetu et al., 2021).

In Rwanda, like in other developing countries, intensive community-based and directed interventions have been adopted and progressively implemented since 2010 to reduce the burden of diarrheal diseases, especially among children under 5 years old, who are the most affected (Ministry of Health, 2010). With noted progressive efforts to significantly reduce diarrhea among children under 5 years old, it was necessary to determine if there is a significant reduction of diarrhea with time nationally and across communities. Such needed reduction of diarrhea requires integrated and area-specific efficacious interventions to address the community, individual, and household-level factors that are associated with diarrhea (Hutton & Chase, 2017).

The research findings of Negesse et al. (2021) in Ethiopia indicated that a reduction in diarrhea of 14% between 2000-2016 was due to behavior change. The Rwanda Demographic Health Surveys (RDHS) reported a national prevalence of diarrhea of 14.1%, 13.2%, 12.1%, and 14.2% in 2005, 2010, 2015, and 2020 respectively among children under 5 years old (National Institute of Statistics of Rwanda [NISR], 2005, 2010,

2015, 2020). Habtu et al. (2017) revealed a higher prevalence of 26.7% of diarrhea among children under 5 years old in the Nyarugenge district in Rwanda. In Ethiopia, a variation in diarrhea prevalence was observed between the urban and rural areas, with higher variation in rural areas and between the 10 regions with a higher variation in Southern Nations, Nationalities and People (SNNP) region (18.5%) and lower variation in Tigray region (4.9%). In Rwanda, Umuhoza et al. (2021), using the dataset of RDHS 2015, confirmed a national prevalence of 12.7% of diarrhea among children under 5 years old and noted an increased risk for diarrhea among children from (a) western province (*OR* = 1.439) and (b) households with poorly educated mothers (*OR* = 5.163). According to Terefe et al. (2023), the problem of reach and access to primary healthcare services can influence the adoption of safe behaviors and practices for reduced diarrhea.

In addition to spatial-temporal factors, individual factors have influence on diarrhea among children under 5 years old. Indeed, research findings of Pintu and Dinabandhu (2020) in India indicated that children whose mothers experienced physical abuse (a*OR* = 1.34, 95% CI[1.21–1.49]), emotional abuse (a*OR* = 1.64, 95% CI[1.45–1.86]), sexual abuse (a*OR* = 1.30, 95% CI[1.07–1.59]), or all forms of violence (a*OR* = 2.08, 95% CI[1.74–2.46]) were more likely to have diarrhea than those whose mothers did not encounter any spousal violence. Cases of domestic violence are reported in Rwanda where 37% among women aged 15-49 have experienced physical violence, 23% have experienced sexual violence, and 46% of ever-married women have experienced spousal physical, sexual, or emotional violence. Moreover, the study conducted by Sinmegn et al. (2014) in Ethiopia revealed that children whose mothers were working

were 2 times more likely to have diarrhea compared to children whose mothers were not working (*COR* = 1.76, 95% CI[1.28, 2.43]).

Water sanitation and hygiene (WASH) conditions are risk factors of cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. Household WASH behaviors including water treatment, water storage, use of latrine, and hand washing, are of critical importance in the prevention and control of diarrhea. The research findings of Nguyen et al. (2021) indicated a 43% reduction in diarrhea in South Africa was associated with home-based water treatment. Furthermore, the results of a systematic review by Wolf et al. (2022) revealed a reduction of up to 50% in diarrhea attributable to home-based water treatment. However, the cluster randomized control trial (cRCT) conducted by Sinharoy et al. (2017) did not find any variation in the prevalence of diarrhea among children under 5 years old despite the intensive implementation of the national community-based environmental promotion program (CBEHPP) and improvements in home-based water treatment and sanitation practices in Rusizi district (Rwanda) between the period of 2013-2017. However, in the Rwamagana district of Rwanda, a RCT showed that using filters for home-based water treatment reduced up to 49% of reported diarrhea among children under 5 years old (Haque et al., 2022). More recent research found an overall diarrheal reduction of 25% attributable to household sanitation (Contreras & Eisenberg, 2019) while handwashing can reduce 41% of diarrhea in Sub-Saharan Africa (Nguyen et al., 2021; Solomon et al., 2021).

Thus, improving the design and the implementation of ongoing and new interventions for maximum reduction of diarrhea among children under 5 years old

requires more information on the trend of diarrhea in time and in space as well as associated factors. Current diarrhea-related studies/evaluations are (a) sporadic and limited in time and space and (b) often unevenly distributed to provide enough insights for improved and adapted implementation of interventions and effective reduction of diarrhea among children under 5 years old (Hutton & Chase, 2017; Ntakarutimana et al., 2022). Consequently, the application of their conclusions and recommendations in other areas may be with a high risk of addressing partial issues that can lead to the loss of resources as well as lives due to the lack of appropriate care.

The present study consisted of a country-wide evaluation to characterize the variation of diarrhea among children under 5 years old between 2010-2020, which is a period of continued efforts to reduce diarrhea nationally and in all 30 districts/ communities of the country. In this study, I intended to indirectly assess the effect of combined efforts (policy, organizational, integrated community-based, and household interventions) on diarrhea by providing a description of the variation of diarrhea between 2010 – 2020 and across communities in Rwanda. So far, publications revealed associated factors with diarrhea are unevenly distributed and can include community-level factors, individual-level factors, and household-level factors (Esrey et al., 1985; Habtu et al., 2017; Manetu et al., 2021; Negesse et al., 2021; Ndikubwimana et al., 2021; Umuhoza et al., 2021).

The findings of this research study were expected to contribute through insights gained to (a) better understand the childhood diarrhea variation and its predictors in time and across communities and (b) guide the improvements in the design and the

implementation of community health interventions to maximize the reduction of diarrhea among children under 5 years old in the context of Rwanda, including hotspots and diarrhea high-risk areas. Through the lens of the socioecological framework, the evidence of key associated community, individual, and household-level factors were considered for necessary information to improve the interventions' outcome in relation to reduction of diarrhea. The research findings were (a) believed to produce global and specific recommendations to guide global (national), community, individual, and household-specific interventions; and (b) expected to inform the design, planning, implementation, and evaluation of integrated community-based interventions for maximum positive effect on reduction of diarrhea among children under 5 years old in communities of Rwanda (Agegnehu et al., 2019; Negesse et al., 2021, Ntakarutimana et al., 2022).

With the growing interest in how WASH interventions might support strategies to reduce diarrheal diseases in sub-Saharan Africa, there is a growing body of evidence suggesting that household WASH behaviors/practices, mothers' social status, and community/environmental conditions are important determinants of diarrhea among children under 5 years old (Bartram & Cairncross, 2010; Darvesh et al., 2017; Habtu et al., 2017, Hutton & Chase, 2017; Manetu et al., 2021, Negesse et al., 2021; Nguyen et al., 2021). Adapted and integrated interventions are needed to address comprehensively household-, mother-, and community-risk factors, including high-risk and area-specific issues zones.

In Rwanda, some substantial reforms have taken place at the national, local, and community levels since 2010 to reduce the burden of diarrheal diseases as the top priority

of the government (Ministry of Health, 2010). The main reforms comprised the revision and adoption of (a) the National Policy of Water Supply and Sanitation, (b) the National Policy of Community Health, (c) the National Policy of Environmental Health, (d) the Community-Based Environmental Health Promotion Program, and (e) the Community-Based Nutrition Protocol, among others, in 2010. Concomitantly, the units of Environmental Health and Community Health in the Ministry of Health (national level) were restructured and reinforced with more staff and increased funding partners while at the local level, the district, the hospital, the sector, and the health center were staffed with environmental health officers, nutritionists, and social affairs in charge to ensure (a) that specific roles and responsibilities in WASH, nutrition, and social interventions are established; and (b) the implementation of related community-based program is effective. At the community level, intensive water sanitation and hygiene and nutrition-related activities including (a) establishment of community hygiene clubs, (b) health education campaigns, (c) savings and credits groups, (d) human security program, (e) village kitchen program, (f) parents evening program, (g) early child development program, (h) monitoring and supportive supervision of households, and (i) marketing and support for increased community participation and self-help initiatives have been progressively implemented since 2010 to increase, build, strengthen, and maintain social networks as well as a community environment that supports the reduction of diarrhea. In 2015, (a) the National Policy of Sanitation was separated from the National Policy of Water Supply for the two to be funded and implemented separately, (b) the National Policy of Community Health was revised, and (c) the implementation of community-based integrated WASH-

nutrition was reinforced by the co-funding from the USAID among other development partners to accelerate the reduction of diarrhea through improved household WASH and nutrition practices. All these efforts from the national level (policy and organizational reforms) to local, community, and household level interventions were intended to significantly reduce the burden of diarrheal diseases in Rwanda (Ekane et al., 2020; Ministry of Health, 2008, 2010, 2015; Ministry of Infrastructure, 2010, 2016, 2016, 2017, 2019).

At the time of this study, there was an apparent stagnant reduction of diarrheal diseases among children under 5 years old with a prevalence of diarrhea of 14.1% and 14.2% in 2005 and 2020 respectively (NISR, 2005, 2020). The research findings of Sinharoy et al. (2017) confirmed no health effect of the national Community-Based Environmental Health Promotion Program adopted in 2010 on the prevalence of diarrhea among children under 5 years old in Rusizi district (one of the 30 districts of the country) in Rwanda. The problem that prompted this research study related to the persistence of the high prevalence of diarrhea in Rwanda after 10 years of policy, institutional, community, and household level control interventions' efforts. The purpose of this research was to provide a better description of the variation of diarrhea and associated factors to help adapt the design of existing interventions and/or improve their implementation for maximum health effect (reduction of diarrhea). The findings of this research study were expected to provide statistical and theoretical facts to guide specific improvements to address risk factors at community, household, and individual levels countrywide for maximum reduction of diarrhea. The design, the planning,

implementation, and evaluation of area-specific interventions for maximum positive effect on the reduction of diarrhea among children under 5 years old in Rwanda is supported by previous research findings (Habtu et al., 2017; Negesse et al., 2021, Ntakarutimana et al., 2022, Sinharoy et al., 2017; Umuhoza, 2021).

Background

Diarrhea's clinical symptoms consist of passing loose or watery stool at least three times during a period of 24 hours. The clinical types of diarrhea commonly include (a) acute watery diarrhea, (b) acute bloody diarrhea, and (c) persistent diarrhea. Acute diarrhea is caused by an infection and includes cholera (watery diarrhea) and shigella dysentery (bloody diarrhea). It starts within 12 hours to 4 days after exposure and lasts 3 to 7 days. Persistent diarrhea is diarrhea with or without blood that starts acutely and lasts equal to or more than 14 days (Negesse et al., 2021; World Health Organization [WHO], 2017). Diarrhea is the second leading cause of death among children under 5 years old worldwide, killing 525,000 children under 5 years old each year (WHO, 2017). In Rwanda, the prevalence of diarrhea was 14.2% in 2020 as a national average and reached 26.7% in some districts like Nyarugenge (Habtu et al., 2017; National Institute of Statistics of Rwanda [NISR], 2020). The dehydration caused by diarrhea is the major cause of illness and death. Diarrhea has been associated with malnutrition (stunting and westing) due to frequent episodes, and malnourished children or children with impaired immunity, including those living with HIV/AIDS, are most at risk of life-threatening diarrhea in addition to economic losses and stress encountered by affected families (WHO, 2017).

The disease is usually transmitted through ingestion of pathogens (mainly Rotavirus, *Escherichia coli*, *cryptosporidium*, and *shigella* in developing countries) from faecally contaminated fluids, mainly water, food, fingers, flies, and soil. The key current measures for diarrhea prevention include (a) access to and use of adequate water (in quantity and in quality), safe sanitation (improved and clean toilet/latrine), adequate hand washing (washing hand at the critical times with water and soap); (b) exclusive breastfeeding for the first 6 months of life; (c) good personal and food hygiene; (d) health education about how infections spread; and (e) rotavirus vaccination. Inadequate water supply sanitation and hygiene conditions account for up to 88% of diarrhea cases, depending on locations. However, interventions for diarrhea prevention, including improvements in water supply, sanitation, and hygiene are not always accompanied by a significant reduction of diarrhea among children under 5 years old. Other community/environmental factors, household behaviors/practices, and mothers' social status need critical attention. Indeed, (a) the safety of the community of residence; (b) the knowledge, the availability, and the readiness of mothers to offer adequate care to children; and (c) the adoption of household water treatment and safe storage, use of improved and clean latrine, washing hand at critical times with water and soap are indispensable to faster the reduction of diarrhea among children under 5 years old (Negesse et al., 2021; Umuhoza et al., 2021; WHO, 2017). At the community level, population density, availability of water and its quality, quality of the soil (hard to dig or fluent soil for construction of pit latrines/toilets), weather conditions (floods and droughts), and accessibility of health care services have an influence on diarrhea among

children under 5 years old (Asare et al., 2022; Das et al., 2023; Jarquin et al., 2016; Negesse et al., 2021; Odiyo et al., 2020; Terefe et al., 2023; Yang et al., 2022). In addition, the mother's role to offer adequate care to the child can be influenced by the level of education, employment status, and the status of being victim of domestic violence or not (Pintu & Dinabandhu, 2020; Zegeye et al., 2021). In terms of household WASH behaviors, the adoption of (a) household water treatment helps to prevent and remove any water contamination from the water source to the point of use; (b) household safe storage of water keeps water out of reach of any agent of contamination (children, pets, rodents, wind, and falling dirt or dirty objects); (c) use of improved and clean latrine/toilet keeps excreta out of reach by agent of transportation and prevents any contamination of the user while offering conditions for its comfortable use; (d) hand washing at critical times (after toilet, before eating, before food preparation, before breastfeeding/feeding the child, after cleaning a child after defection, and after touching dirty objects prevents the ingestion of pathogens through cutting all the routes (fingers, water, food, flies, and ground surface; Contreras & Eisenberg, 2019; Esrey et al., 1985; Nguyen et al., 2021; Solomon et al., 2021). Household WASH practices/behaviors are influenced by habits, the complexity of living conditions of individuals and families, and community-specific conditions among other influencing factors (Busienei et al., 2019; Wasonga et al., 2016).

The prevention of diarrheal diseases has been mainly based on progressive improvement of water supply and sanitation (WHO, 2017). Later there was an established experience that water and sanitation as an element of primary health care integrated with

health education have a health impact if safe behavior/practices of hygiene are adopted (Hutton & Chase, 2017). However, that adoption of safe WASH behavior is not influenced by increasing knowledge of the population only but instead by many more factors (Busienei et al., 2019; Hutton & Chase, 2017; Schlegelmilch et al., 2016). Those factors include but are not limited to (a) access to healthcare services and availability and (b) aptitude of the mother to play the central role for maximum reduction of diarrhea.

The findings of a systematic review conducted by Esrey et al. (1985) from 67 studies conducted in 28 countries estimated a median reduction of diarrhea at 21% due to improvements in water supply and sanitation with a variation range of 1-100% diarrhea reduction. According to Negesse et al. (2021), after analyzing the demographic health surveys (DHS), the data revealed a variation of diarrhea in time and in space and reported that 97% of the change in diarrhea (a drop from 26% in 2000 to 12% in 2016) between 2000-2016 in Ethiopia was attributable to behavior change. Sinharoy et al. (2017) did not find any effect in terms of risk reduction (RR) of a community health education program implemented between 2013 and 2015 on diarrhea among children under 5 years old in Rusizi district of Rwanda despite noted improvements in (a) home-based water treatment (risk reduction [RR] = 20%, 95% CI [12,28], $p < 0.0001$) and (b) sanitation (RR = 14%, 95%CI [5.3,22], $p < 0.001$).

The research works of Umuhoza et al. (2021) highlighted the association of diarrhea with (a) spatial location (*OR* = 1.439 for those from the Western province) and (b) literacy of mothers (*OR* = 5.163 for those with poorly educated mothers), results that were confirmed by Habtu et al. (2017). In the Nyarugenge district, research findings

indicated a higher prevalence of 26.7% with a higher risk of diarrhea among children whose mothers have no education level (adjusted odds ratio [*AOR*] = 3.76; 95% CI [= 1.26-11.24], $p = 0.018$) and primary education level (*AOR* = 2.94; 95% CI [1.04-8.28], $p = 0.042$) compared to those with a tertiary education level (Habtu et al., 2017). Asare et al. (2022), Negesse et al. (2021), Darvesh et al. (2017), Nshimiyimana et al. (2020), Pinzón-Rondón et al. (2015), and Umuhoza et al. (2021) revealed an association between diarrhea and ecological factors, meteorological factors, and sociobehavioral factors in Ghana, Ethiopia, and Rwanda. Therefore, it is not surprising to see a persistence or slow reduction of diarrhea among children under 5 years old at different levels in time and in space despite ongoing WASH interventions (Ntakarutimana et al., 2021; Schlegelmilch et al., 2016; Sinharoy et al., 2017; Winter et al., 2019).

The design and the implementation of effective interventions need strategic adaptations in time and in space to address sociobehavioral factors for a significant reduction of diarrhea among children under 5 years old (Nilima et al., 2018). Consequently, maximizing the reduction of diarrhea among children under-5 years old requires an understanding of factors associated with diarrhea and using them to tailor the ongoing or new interventions design and/or implementation for the matter. In the present research study, I adopted this framework to investigate and to understand the spatial-temporal variation of diarrhea and associated sociobehavioral factors between 2010-2020 in Rwanda. The research findings were expected to contribute to the Rwanda government's priority to accelerate the reduction of diarrhea among children under 5 years old.

Overview of the Manuscripts

The overall problem was addressed through three studies that characterized (a) the spatial-temporal variation of diarrhea between 2010-2020 in Rwanda (Study 1); (b) the influence of mothers' exposure to domestic violence, level of education, and employment status on diarrhea between 2010-2020 in Rwanda (Study 2); and (c) the relationship between household WASH behaviors and diarrhea between 2010-2020 in Rwanda (Study 3).

In the Manuscript 1, I used stratified descriptive analysis, repeated measures, and logistic regression designs. The stratified descriptive analysis design was used to describe the prevalences of diarrhea among children under 5 years old across districts/ communities, regions, and urban-rural areas in 2010, 2015, and 2020. Repeated measures (pairwise comparisons) design was performed to assess the variation of the prevalence of diarrhea in time between 2010-2020. Logistic regression design was used to predict the variation of diarrhea across places of residence, including (a) urban-rural, (b) region, and (c) community/district (Dimitrova et al., 2022; Negesse et al., 2021; Nilima et al., 2018; Pinzón-Rondón et al., 2015; Warner, 2013).

In the Manuscript 2, I assessed the influence of mothers' exposure to domestic violence, education level, and employment status on diarrhea among children under 5 years old in Rwanda. I used logistic regression design to predict the contribution of each of the individual characteristics to having diarrhea for the child. I performed additional statistical analyses to see the prevalence of mothers' characteristics (stratified descriptive analysis design) and their variation with time (pairwise comparisons) for more

information and discussion (Habtu et al., 2017; Manetu et al., 2021; Negesse et al., 2021; Umuhoza et al., 2021; Warner, 2013).

In the Manuscript 3, I assessed the relationship between household water treatment, household safe water storage, use of clean toilet, hand washing behaviors and the prevalence of diarrhea among children under 5 years old in Rwanda. I used (a) stratified descriptive analysis design to assess the prevalence of household WASH behaviors across communities, regions, and urban-rural areas; (b) pairwise comparisons to assess the variation of household WASH behaviors between 2010-2020; and (c) linear regression analysis to predict the contribution of each of the household behaviors to having diarrhea in 2010, 2015, and 2020 (Habtu et al., 2017; Manetu et al., 2021; Negesse et al., 2021; Umuhoza et al., 2021; Warner, 2013).

Significance

The improvements in the design and/or the implementation of intervention to significantly reduce the burden of diarrhea among children under 5 years old in Rwanda require the knowledge of the variation of diarrhea in time and in space and associated factors. The assessment of the variation of diarrhea and associated factors focused on the variation of diarrhea between 2010-2020 and across urban and rural areas, 5 regions, and 30 communities of Rwanda. The results of this study were expected to characterize the variations (in time and in space) countrywide and across urban rural areas, regions, and communities, which can help to (a) visualize the hotspots and high-risk zones for diarrhea, and (b) assess indirectly the effect of combined efforts (policy, organizational, integrated community-based, and household interventions) on the prevalence of diarrhea

among children under 5 years old between 2010-2020. In addition, the study results were expected to describe (a) the prevalence of diarrhea risk factors across urban rural areas, regions, and communities, (b) the variation of diarrhea risk factors, and (c) their relationship with diarrhea in time and across urban-rural areas, regions, and communities in Rwanda between 2010-2020. Diarrhea risk factors of interest included mothers' highest educational level attained, employment status, experience of domestic violence, and household WASH behaviors. The research findings potentially constitute (a) an insight for understanding the multilevel aspect of diarrhea risk factors and the complexity of diarrhea control and (b) a guide to assess and understand the area-specific diarrhea risk factors for improved design and implementation of diarrhea control interventions and maximum reduction of diarrhea among children under 5 years old in communities of Rwanda (Cavalcanti et al., 2019; Nilima et al., 2018; Pinzón-Rondón et al., 2015).

The study findings were expected to highlight the need for assessing and understanding area-specific diarrhea risk factors using the socioecological model. Through questioning the quality design and implementation of diarrhea control interventions, the study findings are expected to inspire improved quality design and effective implementation of area-specific diarrhea control interventions to significantly reduce diarrhea among children under 5 years old in Rwanda. The findings of this research constitute a potential insight for guided policy, organizational, and local adjustments to improve the diarrhea control interventions' outcome (reduction of diarrhea).

The study results are expected to demonstrate the need (a) to improve the quality design, planning, funding, and implementation of area-specific interventions and (b) allocate more efforts and resources to high-risk zones for maximum reduction of diarrhea among children under 5 years old across communities in Rwanda (Cavalcanti et al., 2019; Nilima et al., 2018).

Summary

Efforts to reduce diarrhea in communities in Rwanda are continuously made with annual incremental change in financial, human, and material resources to increase the coverage and the adoption of related interventions. However, at the time of this study, there was a stagnant reduction of diarrhea among children under 5 years old though water supply and sanitation coverage has significantly increased with time countrywide. It was believed that in addition to the availability of water and sanitation, which is high in Rwanda, other factors of influence on the adoption of safe WASH behavior to prevent the ingestion of pathogens and reduce the prevalence of diarrhea needed to be investigated. Particular attention was paid to mothers, household, and community-related factors as relevant for designing and implementing interventions to maximize the reduction of diarrhea. Indeed, the research findings are clear on their significant association with diarrhea among children under 5 years old (Dimitrova et al., 2022; Esrey et al., 1985; Esrey et al. 1991; Habtu et al., 2017; Manetu et al., 2021; Negesse et al., 2021; Pintu & Dinabandhu, 2020; Umuhoza et al., 2021). In the present study, I aimed to understand the variation of diarrhea among children under 5 years old in time and in space and the associated (mothers, household, and community) factors. The purpose of the 3 part-

research study was to characterize the variation of the prevalence of diarrhea and associated mothers, household, and community factors. In the first part, I described the variation of diarrhea in time and in space between 2010-2020 in Rwanda. In the second part, I assessed the influence of mothers' experience of domestic violence, education level, and employment status on the prevalence of diarrhea between 2010-2020 in Rwanda. In the third part, I assessed the relationship between household WASH behaviors and diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Part 2: Manuscripts

Manuscript 1 Title: Spatial- Temporal Variation of Diarrhea Between 2010-2020 in Rwanda

Amans Ntakarutimana

Walden University

Outlet for Manuscript

The findings of this research study helped to describe the variation of diarrhea among children under 5 years old across districts, regions, and urban-rural areas between 2010-2020 in Rwanda. The study results constitute a basis for researchers and policy implementers/ communities respectively for (a) further research on assessing and understanding area-specific diarrhea risk factors and (b) quality design and implementation of area-specific interventions to maximize the reduction of diarrhea among children under 5 years old in Rwanda.

Abstract

The better the understanding of childhood diarrhea occurrence and associated factors at the community level, the better the prevention and control of its associated morbidity rates. I conducted this cross-sectional study to assess the spatial-temporal variation of diarrhea among children under 5 years old between 2010 – 2020 in Rwanda. I used secondary data from 2010, 2015, and 2020 Rwanda Demographic Health Surveys. I used stratified descriptive statistics, repeated measures/pairwise comparisons, and logistic regression designs for data analyses in SPSS. The study results did not show a significant variation in diarrhea among children under 5 years old between 2010-2020. The prevalence of diarrhea among children under 5 years old significantly varies across districts, regions, and urban-rural areas between 2010-2020. Some districts of the Western region, Northern, and Southern regions are at higher risk of diarrhea in 2020 with the Western region being consistently at higher risk of diarrhea among children under 5 years old between 2010-2020. The variation of diarrhea across districts, regions, and urban-rural areas may be due to (a) unevenly spatial distribution of diarrhea risk factors and/or (b) irregularities in the design and implementation of existing diarrhea control interventions. According to the present study results, the effect of existing control interventions on diarrhea is limited between 2010-2020. Area-specific tailored diarrhea control interventions and their effective implementation are required to ensure reduced diarrhea among children under 5 years old across various places of residence in Rwanda.

Introduction

In the efforts to reduce diarrheal diseases, integrated and multifaceted health promotion and prevention interventions have been purposively and progressively revised, adopted, and implemented since 2010 at the community level in Rwanda. However, there is a persistence of high prevalence of diarrhea. The prevalence of diarrhea was 14.1% and 14.2% in 2005 and in 2020 respectively (NISR, 2005&2020). The research findings of Sinharoy et al. (2017) found no health effect of the National Community-Based Environmental Health Promotion Program adopted in 2010 on the prevalence of diarrhea among children under 5 years old in Rusizi district (one of the 30 districts of the country) in Rwanda. Habtu et al. (2017) reported 26.7% prevalence of diarrhea among children under 5 years old in Nyarugenge district despite intensive community-based WASH interventions between 2010 - 2020. We felt the need to understand through a description and a quantification of the variation of diarrhea in time and in space between 2010-2020 in Rwanda as a contribution to orient actions toward improving the interventions' design and or their implementation for significant reduction of diarrhea among children under 5 years old in Rwanda.

Literature Review

The occurrence of diarrhea is unevenly distributed in time and in space and related control interventions should be time and space sensitive taking into consideration spatial-temporal risk factors. In the present study, I assessed the spatial-temporal risk factors using time and space as variables. The subset variables of time used in this assessment are Time 1 (2010), Time 2 (2015), and Time 3 (2020) to quantify the

variation of diarrhea between 2010-2015, 2015-2020, and 2010-2020.The subset variables of space used in this assessment comprised (a) place of residence with values urban and rural, (b) region of residence with values Kigali City, Southern Province, Western Province, Northern Province, and Eastern Province, and (c) community/district of residence with values the 30 different districts of Rwanda.

Time

In terms of time, progressive efforts to improve policies as well as their progressive implementation and improvements in organizational change and funding are believed to make a progressive significant reduction in diarrhea. In Ethiopia, the research findings of Negesse et al. (2021) reported 14% of overall reduction of diarrhea between 2000-2015 from which 97% of the change in diarrhea prevalence was attributable to behavior change with time between 2000-2015. In Rwanda, considerable progressive efforts in terms of resources allocation and changes in systems took place since 2010 to significantly reduce diarrhea among children under 5 years old. According to the data from Rwanda Demographic Health Survey (RDHS) reports of 2010, 2015, and 2020, the overall prevalence of diarrhea was 13.2%, 12.1%, and 14.2% respectively. We used the time to assess the quantity of variation of diarrhea in time to ensure the contribution of the ongoing policies and interventions in terms significant reduction of the prevalence of diarrhea nationally and across communities in Rwanda between 2010-2020.

Space

Within countries, the variation of diarrhea is heterogeneous and consistent with meteorological, geomorphological, ecological, population density, and urban versus rural

conditions creating spatial hotspots of diarrhea. These conditions are not dependent on health systems, but health systems must consider them for efficiency and sustainability in terms of diarrhea reduction.

Referring to meteorological conditions, relative humidity and high temperature are associated with the likelihood of increasing diarrhea. In various places, floods and extremely high temperatures are accompanied by an increased incidence of diarrhea (Yang et al., 2022). According to Asare et al. (2022), temperature and rainfall were positively associated with diarrhea incidence while coastal and transition zones were negatively associated with the incidence of diarrhea in Ghana.

Regarding geomorphological conditions, some regions are difficult to access due to mountainous and rugged terrains. The research findings of Zhang et al. (2017) in China revealed hotspots of diarrhea mainly in mountainous lands which were also qualified as high-risk areas by the study. The North-West of Rwanda is characterized by mountainous lands while the South-East of Rwanda is characterized by flat lands but the relationship between the morphology of lands and diarrhea is not yet established. However, research findings revealed that women at the highest altitudes have limited access to healthcare services and it is presumed that the adoption of health interventions is reduced as well (Corden et al., 2021; Csete, 1993; NISR, 2020; Order-DeWan et al., 2019). According to Terefe et al. (2023), the problem of reach and access to primary healthcare services can influence the adoption of safe behaviors and practices for the prevention of diarrhea. Some regions, like volcanic regions, sandy soil or loose soil regions, and regions with high water-table are respectively not allowing households to have pit latrines which can

lead to (a) poor sanitation conditions and behaviors and (b) increased prevalence of diarrhea. Indeed, such poor soil conditions constitute barriers to the sustained adoption and use of improved latrines in communities because constructing latrines becomes technically and financially challenging for households (Ntakarutimana et al., 2018; Tamene and Afework, 2021). Also, drinking water salinity due to mainly weathering of rocks, precipitation of calcite, dissolution of gypsum and halite in groundwater and surface water, and water contamination, has been found to be associated with diarrhea. In Bangladesh, diarrhea-related hospital visits were found to be significantly associated with high water salinity and total dissolved solids (TDS) with households exposed to high salinity demonstrating a higher frequency of hospital visits than the low salinity-exposed households. Water salinity is a public health concern that will continue to rise due to climate change, but people exposed to high salinity lack awareness regarding salinity-inducing health effects, especially diarrhea (Chakraborty et al., 2019; Rao et al., 2022). The areas with high water table and volcanic regions with high permeability rocks, both underground and surface water are likely to be contaminated by agricultural activities, domestic waste, animal waste, and human waste (fecal contamination) from pit latrines, defective septic tanks, and broken sewers. Such above-mentioned soil and hydrogeology conditions prevail particularly in the Northern, Western, and Southern regions of Rwanda.

The resultant sanitary conditions including the potential (a) lack of adequate latrines and (b) contamination of groundwater and surface water increase the likelihood of diarrhea among exposed households than in non-exposed households. In the Limpopo

Province of South Africa, the annual risks of infection due to *E. coli* and *Shigella flexneri* were 89.11 and 83.75%, respectively with maximum risks of illness per year being 31.19 and 29.31% for *E. coli* and *Shigella flexneri*, respectively. Special consideration on infrastructure and awareness raising must be taken to reduce the prevalence of diarrhea in these areas (Odiyo et al., 2020). In terms of ecology, forest and savannah zones were reported positively associated with diarrhea incidence in Ghana (Asare et al., 2022). In a home environment, research findings proved that (a) 37% of children ingest earth occasionally with less than a handful and 12% of children ingest a lot with a handful or more, (b) diarrhea was positively correlated with the presence of human feces in the yard ($r = 0.587$), and (c) earth eating was significantly related to diarrhea ($p < 0.005$) (Shivoga & Moturi, 2009).

The community/district-level population density has been proven to be a strong predictor of risks of diarrhea in Ecuador, Ghana, and Guatemala. Research findings have reported higher diarrhea risk in high-density areas versus low-density due to *Shigella* spp. (IRR = 1.38, 95% CI [1.00, 1.90]), and rotavirus (IRR = 1.56, 95% CI [1.03, 2.36]) (Asare et al., 2022; Jarquin et al., 2016). The research findings of Bates et al. (2007) reported approximately 3.3 times the incidence of diarrheal in the highest housing density than in the lowest housing density communities in Ecuador.

Regarding urban-rural conditions, the prevalence of diarrhea tends to be lower in urban areas than in rural areas. Indeed, access to healthcare services and utilization is due to various reasons including availability of infrastructure, human and material resources, service delivery, and beneficiaries' characteristics including awareness and financial

issues. Rural and peri-urban areas are underserved compared to urban areas in terms of healthcare services. But also, the utilization of healthcare services differs as well as the prevalence of diarrhea among children under 5 years old. In terms of the availability of infrastructure, healthcare facilities are unevenly distributed with a larger number and closer to the population in urban areas than in rural areas. The distance to healthcare facilities has a high influence on the prevalence of diarrhea. In Ethiopia, the prevalence of diarrhea in 2016 was 2.7 times for children located far from the health center compared to those located closer (Negesse et al., 2021). In Rwanda, research findings revealed that women at the highest altitudes have limited access to healthcare services and it is presumed that the adoption of health interventions is reduced too (Corden et al., 2021; Csete, 1993; Negesse et al., 2021; NISR, 2020; Order-DeWan et al., 2019).

In terms of human and material resources, qualified and specialized personnel as well as awareness raising, health education, and medical equipment are more accessible in urban areas than in rural areas. This positively influences the quality-of-service delivery and coverage, which are higher in urban than in rural areas with implications on the differences in the prevalence of diarrhea (Elshabassi et al., 2023; Masanja et al., 2019). Diarrhea is influenced by the adoption and utilization of healthcare services and related behavior which in their turn differ from Urban to rural areas depending on the different levels of (a) awareness of the importance of hygiene, immunization, nutrition, and care-seeking, (b) Poverty and lifestyle as factors for poor health behaviors, and (c) health system inefficiencies adding to the lack of equipment and supplies, resources, and funding more frequent in rural facilities (Das et al., 2023). The problem of reach and

access to primary healthcare services can influence the adoption of safe behaviors and practices for reduced diarrhea according to Terefe et al. (2023). In Rwanda, the prevalence of diarrhea is 11.5% and 148% as reported by the 2020 DHS in urban and rural areas respectively. There is a need to assess the variation of diarrhea in urban and rural areas in the context of Rwanda between 2010-2020. The present study will assess the variation of diarrhea in urban and rural areas in Rwanda between 2010-2020 and across communities.

With a supposedly uneven distribution of spatial risk factors of diarrhea, some communities may need specific, improved, and/or adapted interventions (healthcare, infrastructure, health education) and more efforts and skills of local leaders and health professionals to reduce the prevalence of diarrhea through solving local-specific issues using the maximum available local resources and capacities for the efficiency and sustainability of solutions and their health outcomes (Ghimire et al., 2010; Mbakaya et al., 2019). The RDHS reported in 2020 a prevalence of 11.7%, 13.1%, 18.4%, 16.2%, and 11.4% in Kigali City, Southern Province, Western Province, Northern Province, and Eastern Province respectively. The variation of the prevalence of diarrhea and its quantity of variation is not known between 2010-2020 across communities in Rwanda. There is a need to assess the variation of diarrhea in space to ensure ongoing policies and interventions are making changes in diarrhea with consideration of reducing various diarrhea risk factors across communities in Rwanda between 2010-2020.

What Is Known and Research Gap

Diarrhea's clinical symptoms consist of passing loose or watery stool at least three times during a period of 24 hours. The clinical types of diarrhea commonly include (a) acute watery diarrhea, (b) acute bloody diarrhea, and (c) persistent diarrhea. Acute diarrhea is caused by an infection and includes cholera (watery diarrhea) and shigella dysentery (bloody diarrhea). It starts within 12 hours to 4 days after exposure and lasts 3 to 7 days. Persistent diarrhea is diarrhea with or without blood that starts acutely and lasts equal to or more than 14 days (World Health Organization [WHO], 2017; Negesse et al., 2021). Diarrhea is the second leading cause of death among children under 5 years old worldwide killing 525,000 children under 5 years old each year. In Rwanda, the prevalence of diarrhea is 14.2% (in 2020) national average according to the 2020 Rwanda Demographic Health Survey. The dehydration caused by diarrhea is the major cause of illness and death. Diarrhea is associated with malnutrition (stunting and westing) due to frequent episodes and malnourished children or children with impaired immunity including those living with HIV/AIDS are most at risk of life-threatening diarrhea in addition to economic losses and stress encountered by affected families (Habtu et al., 2017; National Institute of Statistics of Rwanda [NISR], 2020; WHO, 2017). The disease is usually transmitted through ingestion of pathogens (mainly Rotavirus, *Escherichia coli*, *cryptosporidium,* and *shigella* in developing countries) from faecally contaminated fluids (mainly water), food, fingers, flies, and soil. In Rwanda, new policies, strategies, interventions, and progressive improvements for diarrheal diseases control have been adopted and implemented since 2010 as documented by Ekane et al. (2020), Rwanda

Ministry of Health (2008,2010,2015, 2017 & 2018), Rwanda Ministry of Infrastructure (2010, 2016, 2016, 2017&2019) and USAID (2015). Table 1 aligns the main policy and strategic interventions.

Table 1

Main Policy and Strategic Interventions Since 2010

2005-2010	2010-2015	2015-2020
Reference period with data from the RDHS 2010	Revision and implementation of the revised National policy of water supply and sanitation since 2010	Separate implementation and funding of the National policy of sanitation and the National policy of water supply since 2016
	Adoption and implementation of the National policy of community health since 2010	Revision and implementation of the revised National policy of community health
	Adoption and implementation of the National policy of Environmental Health since 2010	
	Adoption and progressive implementation of the Community-Based Environmental Health Promotion Program since 2010	
	Adoption and implementation of the Community-Based Nutrition Protocol since 2010	
	Restructuring and reinforcement of the Environmental Health and Community Health units in the Ministry of Health (National level) with more staff and increased funding partners since 2010	
	Progressive appointment at local level, the district and the hospital of Environmental Health Officers, Community health officers to ensure to support the implementation, monitoring, and evaluation of related community-based program since 2010	
	Appointment at community level, the sector and the health center of Environmental Health Officers, Sanitation and Hygiene officers, Nutritionists, social affairs, and health promotion in charge to ensure (1) specific roles and responsibilities in water sanitation and hygiene (WASH), nutrition, community health, and social interventions are established and (2) effective implementation of related community-based program and reporting since 2010.	
	Establishment and progressive implementation of (1) Community hygiene clubs, (2) health education campaigns, (3) savings and credits groups, (4) human security program, (5) village kitchen program, (6) parents evening program for family issues and counseling, (7) increased community participation and self-help initiatives with the introduction of performance contracts at community and household levels since 2010.	
		Accelerated implementation of community-based integrated WASH-Nutrition with additional co-funding and staffing from the USAID in 7 districts of Rwanda since 2015 (Kayonza, Kicukiro, Ngoma, Nyabihu, Nyarugenge, Nyanza, Nyabihu).

So far in Rwanda, at the time of the study, there was no study yet conducted to assess the variation of diarrhea among children under 5 years old in time and across

communities between 2010-2020. The demographic health surveys of 2010, 2015, and 2020 show a prevalence of diarrhea of 13.2%, 12.1%, and 14.2% respectively at the national level but there is no proof that the observed figures are statistically significant. The Rwanda Demographic Health Surveys between 2010-2020 reported differences in the prevalence of diarrhea between urban and rural areas, regions (provinces), and communities (districts). The study findings of Sinharoy et al. (2017) suggest no effect of the national community-based environmental health promotion program (a water sanitation and hygiene health promotion program) on the prevalence of diarrhea among children under 5 years old in one of the 30 districts of the country between 2013 and 2015. According to Waterkeyn et al. (2020), the national community-based environmental health promotion program (CBEHPP) was effectively implemented only in 10% of communities in the same Rusizi district with 80% of the adoption of safe WASH practices. The study findings of Nshimiyimana et al. (2021) using Health Management Information System (HMIS) data for new cases of diarrheal revealed a significant variation of diarrheal diseases incidence across the communities/ districts in Rwanda and a significant increase in diarrheal diseases incidence between 2016 and 2018. The highest relative risk was observed in Kirehe district (RR=2.48) while the lowest relative risk was observed in the Southern and Western provinces (RR=1.33). in the present study, I intended to ensure if efforts made since 2010 have made significant positive changes in diarrhea among children under 5 years old.

In this research study, I aimed to describe the variation of diarrhea in time and in space between 2010-2020 in Rwanda using four Rwanda Demographic Health Survey (RDHS) datasets of 2010, 2015, and 2020.

Significance of the Study

In the present research study, I assessed the variation of diarrhea among children under 5 years old between 2010 – 2020 across urban-rural areas, 5 regions, and 30 communities. The findings are expected to show indirectly the effect of combined efforts (policy, organizational, integrated community-based, and household interventions) on the prevalence of diarrhea by providing a description and a quantification of its variation between 2010 – 2020 across communities. This research study results are expected to visualize hotspot areas and high-risk regions but also to suggest improvements in the design and/or the implementation of area-specific interventions with more efforts and resources directed at high-risk zones. Indeed, the better understanding of childhood diarrhea occurrence and associated factors at the community level, the better prevention and control of its associated morbidity rates through addressing associated at community, individual and household factors (Akinyemi et al., 2019; Asare et al., 2022; Nilima et a., 2018). The theoretical framework for this research consisted of a socioecological model which was used to connect community risk factors and health, individual risk factors and health, and household risk factors and health. Indeed, community risk factors vary across communities and over time and have influence on health status of respective community individual members and families. In terms of community factors, urban and rural areas, regions, and communities in Rwanda may differ in the access and utilization of

healthcare services, organization, available skills and resources, and infrastructure to (a) reduce the numerous social, structural, and environmental stressors that affect health but that are beyond the ability of any one person to control or change and (b) strengthen the situational factors (social support, community empowerment, community health stakeholders skills and capacity, community cohesion) that protect against the effects of stress on health to promote good health (Akinyemi et al., 2019; Alemu et al., 2017; Glanz & Bishop, 2010; National Academies of Sciences, Engineering, and Medicine, 2001; Pinzón-Rondón et al., 2015).

Purpose of the Study, Research Questions, and Hypotheses

The purpose of the research was to assess the spatial-temporal variation of diarrhea among children under 5 years old between 2010-2020 in Rwanda. The findings of this research are expected to be an insight to guide further (a) investigations on the identified hotspots and high-risk zones and (b) discussions to improve the design and/or the implementation of area-specific interventions for maximum reduction of diarrhea.

Research question 1: Does the prevalence of diarrhea among children under 5 years old significantly vary between 2010-2020 in Rwanda?

$H_0$1: There is no variation of diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_1$1: There is a variation of diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Research Question 2: Is there any significant spatial (across urban-rural, regions, and communities) variation of diarrhea among children under 5 years old between 2010-2020 in Rwanda?

$H_0$2: There is no spatial variation in diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_1$2: There is a spatial variation of diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Methods

Data Collection and the Study Participants

In this study, I used secondary data from the National Institute of Statistics of Rwanda and the study participants are **c**hildren under 5 years old in Rwanda with a sample of 8,605 children, 7,694 children, and 8,020 children for the 2010, 2015, and 2020 surveys respectively.

Variables

Independent variables are time and space but have been subdivided into subset variables to be operational. The time is decomposed into Time1 (2010-2015), Time 2 (2015-2020), and Time 3 (2010-2020). The space is decomposed into (a) place of residence with values urban and Rural, (b) region of residence with values Kigali City, Southern Province, Western Province, Northern Province, and Eastern Province, and (c) community of residence with values the 30 different districts of Rwanda. The dependent variable is the prevalence of diarrhea among children under 5 years old. The source of

data is the Rwanda Demographic Health Surveys of 2010, 2015, and 2020 datasets from the Rwanda National Institute of Statistics.

Design and Analysis

The research design consisted of cross-sectional design and used (a) stratified descriptive statistics to assess the prevalence of diarrhea among children under 5 years old between 2010-2020 across districts, regions, and urban-rural areas, (b) repeated measures analysis (pairwise comparisons) to assess the variation of diarrhea among children under 5 years old over time between 2010-2020 (variation in time), and (c) logistic regression to assess the variation of diarrhea across 30 districts/ communities, 5 provinces, and urban-rural areas (variation in space) in Rwanda.

Results

I used secondary data from the National Institute of Statistics of Rwanda and collected datasets on (a) child's health and child-mother's social demographic characteristics of the Demographic Health Surveys 2010, 2015, and 2020. Data analysis and interpretation of results followed data cleaning including re-coding of some variables and removal of missing data. The dependent variable (health outcome) was diarrhea among children under 5. The independent variables (predictors) included (a) time (2010, 2015, and 2020) and (b) space (30 districts/communities, 5 regions, and urban-rural). The final sample for children was 8,418 for 2010; 7,474 for 2015; and 7,755 for 2020.

Stratified Descriptive Statistics

Descriptive Statistics analysis was conducted to calculate the prevalence of diarrhea among children under 5 years old per community, region, and urban-rural areas

per year. The national average of diarrhea was also calculated per year. Data on diarrhea are fully presented for regions, and urban-rural areas between 2010-2020 and the national prevalence of diarrhea among children under 5 years old is 13.2%, 12.1%, and 14.2% in 2005, 2010, 2015, and 2020 respectively (see Table 2). Because of the administrative reforms in Rwanda between 2005 and 2010, the communities/districts of 2005 do not match with the communities/districts of 2010, 2015, and 2020. The calculations will then use the data collected between 2010-2020 for the sections ahead. Table 2 and Figures 1 and 2 show the prevalence of diarrhea across districts. Δ_1, Δ_2, and Δ_3 represent respectively the difference in diarrhea prevalence between 2010-2015, between 2015-2020, and between 2010-2020. The difference has a +/- sign in case the prevalence of diarrhea increased/decreased respectively between the indicated time period.

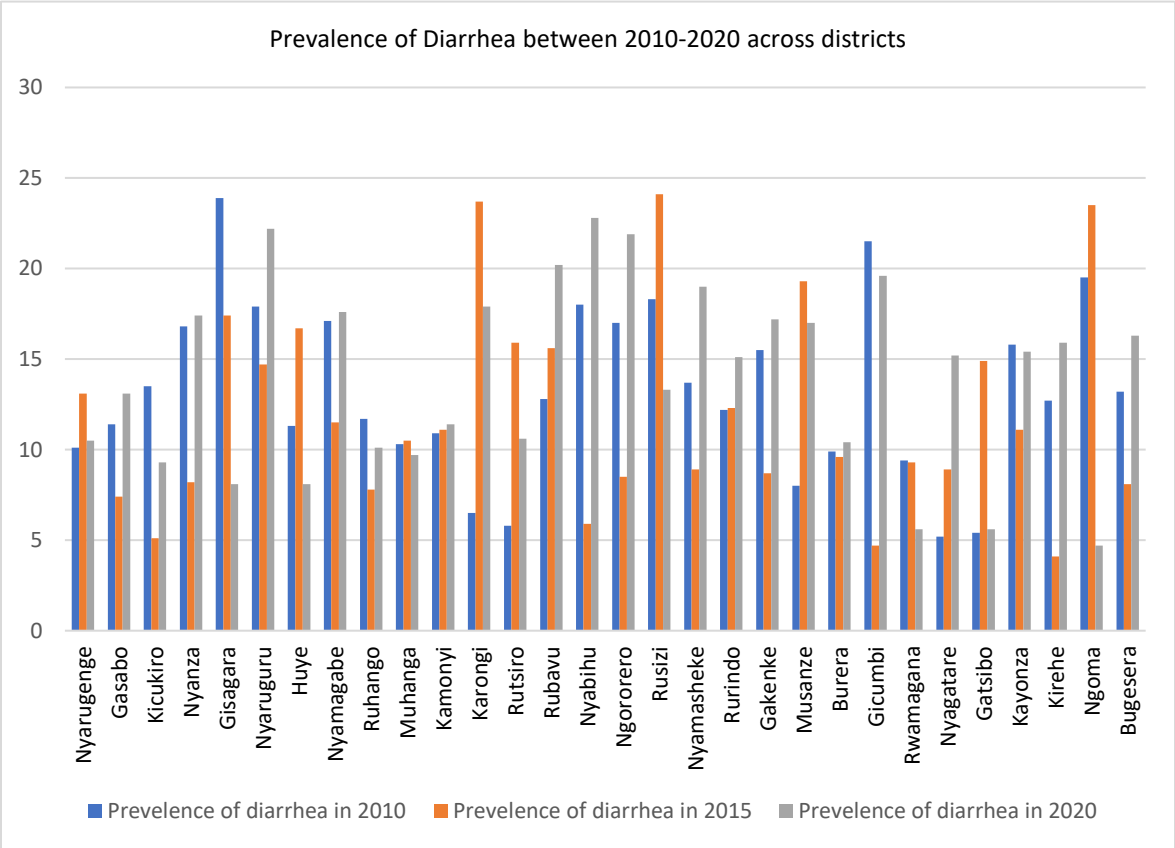
Table 2

Prevalence of Diarrhea Between 2010-2020 Across Communities, Regions, Urban-Rural Areas

Location	Prev2010	Prev2015	Prev2020	Δ_1	Δ_2	Δ_3
Community						
Nyarugenge	10.1	13.1	10.5	+3	-2.6	+0.4
Gasabo	11.4	7.4	13.1	-4	5.7	+1.7
Kicukiro	13.5	5.1	9.3	-8.4	4.2	-4.2
Nyanza	16.8	8.2	17.4	-8.6	9.2	+0.6
Gisagara	23.9	17.4	8.1	-6.5	-9.3	-15.8
Nyaruguru	17.9	14.7	22.2	-3.2	7.5	+4.3
Huye	11.3	16.7	8.1	+5.4	-8.6	-3.2
Nyamagabe	17.1	11.5	17.6	-5.6	6.1	+0.5
Ruhango	11.7	7.8	10.1	-3.9	2.3	-1.6
Muhanga	10.3	10.5	9.7	+0.2	-0.8	-0.6
Kamonyi	10.9	11.1	11.4	+0.2	0.3	+0.5
Karongi	6.5	23.7	17.9	+17.2	-5.8	+11.4
Rutsiro	5.8	15.9	10.6	+10.1	-5.3	+4.8
Rubavu	12.8	15.6	20.2	+2.8	4.6	+7.4
Nyabihu	18	5.9	22.8	-12.1	16.9	+4.8
Ngororero	17	8.5	21.9	-8.5	13.4	+4.9
Rusizi	18.3	24.1	13.3	+5.8	-10.8	-5
Nyamasheke	13.7	8.9	19	-4.8	10.1	+5.3
Rurindo	12.2	12.3	15.1	+0.1	2.8	+2.9
Gakenke	15.5	8.7	17.2	-6.8	8.5	+1.7
Musanze	8	19.3	17	+11.3	-2.3	+9
Burera	9.9	9.6	10.4	-0.3	0.8	+0.5
Gicumbi	21.5	4.7	19.6	-16.8	14.9	-1.9
Rwamagana	9.4	9.3	5.6	-0.1	-3.7	-3.8
Nyagatare	5.2	8.9	15.2	+3.7	6.3	+10
Gatsibo	5.4	14.9	5.6	+9.5	-9.3	+0.2
Kayonza	15.8	11.1	15.4	-4.7	4.3	-0.4
Kirehe	12.7	4.1	15.9	-8.6	11.8	+3.2
Ngoma	19.5	23.5	4.7	+4	-18.8	-14.8
Bugesera	13.2	8.1	16.3	-5.1	8.2	+3.1
Region						
Kigali city	11.7	8.7	11.1	-3	2.4	-0.6
Southern	15.3	12.4	13.3	-2.9	0.9	-2
Western	13.2	14.6	17.8	+1.4	3.2	+4.6
Northern	13.5	10.9	15.8	-2.6	4.9	+2.3
Eastern	11.4	11.6	11.8	+0.2	0.2	+0.4
Urban-rural						
Urban	13.6	10.3	11.5	-3.3	1.2	-2.1
Rural	13.1	12.6	15	-0.5	2.4	+1.9
Total average	**13.2**	**12.1**	**14.2**	**-1.1**	**2.1**	**+1**
Total sample	**8, 418**	**7, 474**	**7, 755**			

Figure 1

Prevalence of Diarrhea Between 2010-2020 Across Districts in Rwanda



Repeated Measures Analysis (Pairwise Comparisons)

Pairwise comparisons were performed to assess the variation in the prevalence of diarrhea in time, based on data collected from communities in 2010, 2015, and 2020. According to Table 3, there is no significant variation in diarrhea prevalence between 2010-2015, 2015-2020, and 2010-2020 ($p > 0.05$).

Table 3

Variation of Diarrhea Between 2010-2020

(I) Community diarrhea	(J) Community diarrhea	Mean difference (I-J)	Std. Error	Sig.	95% Confidence Interval for difference	
					Lower bound	Upper bound
1	2	1.157	1.372	.406	-1.649	3.962
	3	-.863	1.092	.436	-3.097	1.371
2	1	-1.157	1.372	.406	-3.962	1.649
	3	-2.020	1.543	.201	-5.176	1.136
3	1	.863	1.092	.436	-1.371	3.097
	2	2.020	1.543	.201	-1.136	5.176

Logistic Regression

Logistic regression analysis was performed to assess the variation of diarrhea among children under 5 years old across communities, regions, and urban-rural areas. Taking Nyarugenge district located in Kigali City as a reference, table 4 shows the districts of Nyanza (*OR* = 1.804, 95%CI[1.089;2.990], *p* = .022), Gisagara (*OR* = 2.799, 95%CI[1.767;4.433], *p* < 0.001), Nyaruguru (*OR* = 1.45, 95%CI[1.205;3.139], *p* = .006), Nyamagabe (*OR* = 1.844, 95%CI[1.124;3.026], *p* = .015), Nyabihu (*OR* = 1.961, 95%CI[1.215;3.615], *p* = .006), Ngororero (*OR* = 1.832, 95%CI[1.126;2.980], *p* = 0.015), Rusizi (*OR* = 1.997, 95%CI[1.239;3.219], *p* = 0.005), Gicumbi (*OR* = 2.452, 95%CI[1.518;3.961], *p* <0.001), Kayonza (*OR* = 1.672, 95%CI[1.011;2.767], *p* =0.045), and Ngoma (*OR* = 2.163, 95%CI[1.338; 3.497], *p* = 0.002) have a statistically significant higher prevalence of diarrhea in 2010. The districts of Rutsiro (*OR* = 0.545, 95%CI[0.297;1.000], *p* =0.050), Nyagatare (*OR* = 0.491, 95%CI[0.265;0.911], *p* = 0.024), and Gatsibo (*OR* = 0.511, 95%CI[0.276;0.948], *p* = 0.033) have a statistically

significant lower prevalence of diarrhea among children under 5 years compared to Nyarugenge district of Kigali City in 2010. Other districts have no statistically significant difference compared to the Nyarugege district prevalence in 2010. Among regions, Kigali City was taken as a reference among other regions while urban areas were taken as the reference for the comparison urban-rural areas. The Southern region had a statistically significant higher prevalence of diarrhea (*OR* = 1.370, 95%CI[1.085;1.729], *p* = 0.008) compared to Kigali City in 2010. There was no statistically significant difference between other regions and Kigali City as well as between urban and rural areas of Rwanda in 2010. Table 4 shows the variation of diarrhea across communities, regions, and urban-rural areas in 2010 in Rwanda.

Table 4

Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2010

Location	Diarrhea							
							95% C.I.	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Community/ district								
Gasabo	.141	.260	.295	1	.587	1.152	.692	1.917
Kicukiro	.331	.255	1.681	1	.195	1.393	.844	2.298
Nyanza	.590	.258	5.247	1	.022	1.804*	1.089	2.990
Gisagara	1.029	.235	19.240	1	<.001	2.799*	1.767	4.433
Nyaruguru	.665	.244	7.426	1	.006	1.945*	1.205	3.139
Huye	.134	.269	.249	1	.618	1.143	.675	1.937
Nyamagabe	.612	.253	5.863	1	.015	1.844*	1.124	3.026
Ruhango	.172	.281	.376	1	.540	1.188	.685	2.061
Muhanga	.022	.292	.006	1	.940	1.022	.576	1.813
Kamonyi	.084	.278	.091	1	.763	1.088	.631	1.874
Karongi	-.470	.316	2.209	1	.137	.625	.336	1.162
Rutsiro	-.607	.310	3.835	1	.050	.545*	.297	1.000
Rubavu	.267	.261	1.050	1	.305	1.306	.784	2.178
Nyabihu	.673	.244	7.603	1	.006	1.961*	1.215	3.165
Ngororero	.605	.248	5.939	1	.015	1.832*	1.126	2.980
Rusizi	.692	.244	8.069	1	.005	1.997*	1.239	3.219
Nyamasheke	.349	.257	1.847	1	.174	1.418	.857	2.346
Rurindo	.218	.282	.598	1	.439	1.243	.716	2.159
Gakenke	.496	.254	3.804	1	.051	1.642	.998	2.701
Musanze	-.250	.298	.706	1	.401	.778	.434	1.396
Burera	-.016	.285	.003	1	.955	.984	.562	1.721
Gicumbi	.897	.245	13.450	1	<.001	2.452*	1.518	3.961
Rwamagana	-.074	.282	.068	1	.794	.929	.535	1.615
Nyagatare	-.710	.315	5.090	1	.024	.491*	.265	.911
Gatsibo	-.671	.315	4.533	1	.033	.511*	.276	.948
Kayonza	.514	.257	4.006	1	.045	1.672*	1.011	2.767
Kirehe	.260	.262	.981	1	.322	1.297	.775	2.169
Ngoma	.772	.245	9.912	1	.002	2.163*	1.338	3.497
Bugesera	.344	.251	1.884	1	.170	1.411	.863	2.305
Region								
Southern	.315	.119	7.003	1	.008	1.370*	1.085	1.729
Western	.142	.121	1.370	1	.242	1.153	.909	1.463
Northern	.169	.131	1.663	1	.197	1.184	.916	1.531
Eastern	-.024	.124	.038	1	.846	.976	.766	1.244
Urban-rural								
Rural	-.043	.093	.217	1	.641	.958	.798	1.149

*. Statistically significant at the .05 level.

Table 5 shows the districts that have a statistically significant high prevalence of diarrhea including Karongi (*OR* = 2.068, 95%CI[1.309; 3.267], *p* = 0.002), Rusizi (*OR* = 2.126, 95%CI[1.386; 3.260], *p* < 0.001), and Ngoma (*OR* = 2.041, 95%CI[1.325;3.144], *p* = 0.001) while the districts of Gasabo (*OR* = 0.529, 95%CI[0.309;0.907], *p* = 0.021), Kicukiro (*OR* = .354, 95%CI[0.185;0.678], *p* = 0.002), Nyabihu (*OR* = 0.419, 95%CI[0.222;0.791], *p* = 0.007), Gicumbi (*OR* = .324, 95%CI[0.158;0.664], *p* = 0.002), and Kirehe (*OR* = 0.284, 95%CI[0.138;0.581], *p* < 0.001) have a statistically significant low prevalence of diarrhea compared to Nyarugenge district of Kigali City. Compared to Kigali city, the Southern (*OR* = 1.486, 95%CI[1.131; 1.953], *p* = 0.004), Western (*OR* = 1.795, 95%CI[1.373; 2.346], *p* < 0.001), and Eastern (*OR* =1.384, 95%[1.051; 1.822], *p* = 0.021) regions had a statistically significant high prevalence of diarrhea. The prevalence of diarrhea in rural areas (*OR* =1.261, 95%CI[1.056; 1.506], *p* =.010) was higher compared to urban areas in 2015.

Table 5

Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2015

Location	Diarrhea							
							95% C.I.	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Community/ district								
Gasabo	-.636	.275	5.349	1	.021	.529*	.309	.907
Kicukiro	-1.038	.331	9.807	1	.002	.354*	.185	.678
Nyanza	-.522	.293	3.168	1	.075	.593	.334	1.054
Gisagara	.336	.237	2.012	1	.156	1.400	.879	2.229
Nyaruguru	.139	.244	.322	1	.570	1.149	.712	1.854
Huye	.291	.247	1.379	1	.240	1.337	.823	2.172
Nyamagabe	-.149	.272	.301	1	.583	.861	.506	1.468
Ruhango	-.580	.311	3.483	1	.062	.560	.305	1.030
Muhanga	-.248	.278	.795	1	.373	.780	.452	1.346
Kamonyi	-.185	.268	.474	1	.491	.831	.491	1.407
Karongi	.727	.233	9.693	1	.002	2.068*	1.309	3.267
Rutsiro	.230	.239	.924	1	.336	1.258	.788	2.009
Rubavu	.207	.232	.797	1	.372	1.231	.780	1.940
Nyabihu	-.869	.324	7.213	1	.007	.419*	.222	.791
Ngororero	-.486	.284	2.922	1	.087	.615	.352	1.074
Rusizi	.754	.218	11.942	1	<.001	2.126*	1.386	3.260
Nyamasheke	-.432	.258	2.799	1	.094	.649	.392	1.077
Rurindo	-.067	.266	.063	1	.801	.935	.555	1.577
Gakenke	-.460	.319	2.079	1	.149	.631	.338	1.180
Musanze	.464	.246	3.563	1	.059	1.591	.982	2.577
Burera	-.352	.281	1.567	1	.211	.703	.405	1.220
Gicumbi	-1.126	.366	9.484	1	.002	.324*	.158	.664
Rwamagana	-.380	.270	1.977	1	.160	.684	.403	1.161
Nyagatare	-.434	.277	2.460	1	.117	.648	.377	1.114
Gatsibo	.154	.241	.409	1	.523	1.167	.727	1.872
Kayonza	-.189	.260	.530	1	.467	.828	.497	1.377
Kirehe	-1.258	.365	11.898	1	<.001	.284*	.139	.581
Ngoma	.714	.220	10.487	1	.001	2.041*	1.325	3.144
Bugesera	-.529	.284	3.471	1	.062	.589	.338	1.028
Region								
Southern	.396	.139	8.082	1	.004	1.486*	1.131	1.953
Western	.585	.137	18.311	1	<.001	1.795*	1.373	2.346
Northern	.249	.156	2.550	1	.110	1.283	.945	1.742
Eastern	.325	.140	5.353	1	.021	1.384*	1.051	1.822
Urban-rural								
Rural	.232	.090	6.586	1	.010	1.261*	1.056	1.506

*. Statistically significant at the .05 level.

Table 6 shows districts including Nyanza (*OR* = 1.796, 95%CI[1.071;3.011], *p* = 0.026), Nyaruguru (*OR* = 2.427, 95%CI[1.491;3.952], *p* < 0.001), Nyamagabe (*OR* = 1.822, 95%CI[1.089;3.047], *p* = 0.022), Karongi (*OR* = 1.857, 95%CI[1.127;3.061], *p* = 0.015), Rubavu (*OR* = 2.155, 95%CI[1.340;3.466], *p* = 0.002), Nyabihu (*OR* = 2.519, 95%CI[1.564;4.057], *p* < 0.001), Ngororero (*OR* = 2.385, 95%CI[1.467;3.876], *p* < 0.001), Nyamasheke (*OR* = 2.004, 95%CI[1.237;3.247], *p* = .005), Gakenke (*OR* = 1.767, 95%CI[1.054;2.962], *p* = 0.031), Musanze (*OR* = 1.747, 95%CI[1.066;2.865], p=0.027), Gicumbi (*OR* = 2.073, 95%CI[1.255;3.424, *p* = 0.004), Bugesera (*OR* = 1.656, 95CI[1.013;2.708], *p* = 0.044). the districts of Gatsibo (*OR* = 0.510, 95%CI[0.263;0.988], *p* = 0.046) and Ngoma (*OR* = 0.416, 95%CI[0.203;0.853], *p* = 0.017) have a lower prevalence of diarrhea compared to reference district (Nyarugenge). Other districts are not significantly different from the reference district in the prevalence of diarrhea among children under 5 years old in 2020. The Western (*OR* = 1.732, 95%CI[1.368; 2.193], *p* < 0.001) and Northern (*OR* = 1.496, 95%[1.157; 1.934], *p* = .002) regions had a statistically significant high prevalence of diarrhea while Southern and Eastern regions have no difference in diarrhea compared to the reference region (Kigali City) in 2020. The prevalence of diarrhea in rural areas (*OR* = 1.355, 95%CI[1.147; 1.601], *p* < 0.001) was higher compared to urban areas in 2020.

Table 6

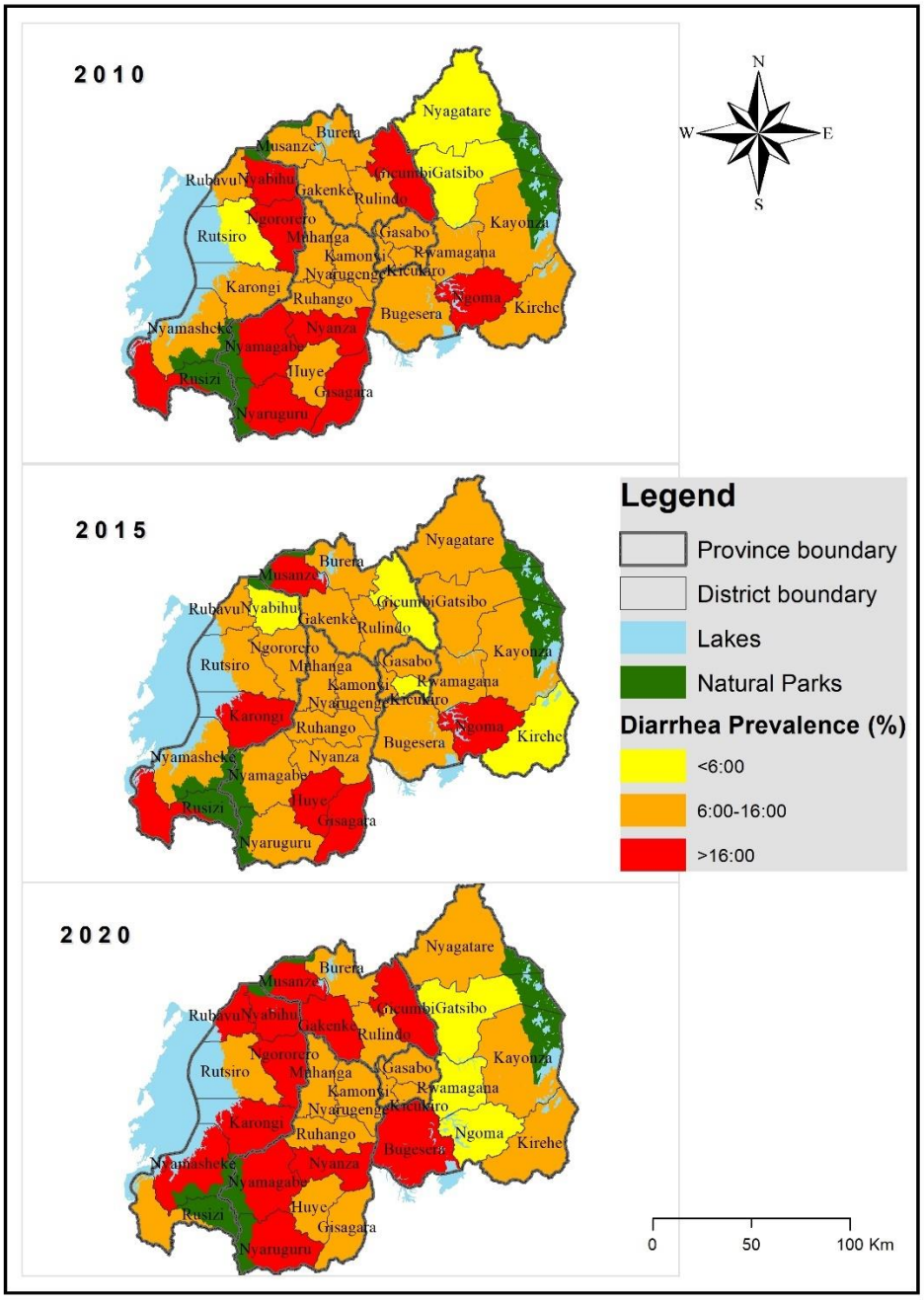
Variation of Diarrhea Across Communities, Regions, and Urban-Rural Areas in 2020

Location	Diarrhea							
							95% C.I.	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Community/ district								
Gasabo	.246	.251	.961	1	.327	1.279	.782	2.092
Kicukiro	-.141	.284	.246	1	.620	.868	.497	1.517
Nyanza	.585	.264	4.924	1	.026	1.796*	1.071	3.011
Gisagara	-.284	.310	.842	1	.359	.753	.410	1.381
Nyaruguru	.887	.249	12.704	1	<.001	2.427*	1.491	3.952
Huye	-.289	.326	.786	1	.375	.749	.395	1.420
Nyamagabe	.600	.262	5.224	1	.022	1.822*	1.089	3.047
Ruhango	-.041	.295	.019	1	.891	.960	.539	1.711
Muhanga	-.093	.306	.093	1	.761	.911	.500	1.661
Kamonyi	.090	.296	.093	1	.761	1.094	.613	1.955
Karongi	.619	.255	5.892	1	.015	1.857*	1.127	3.061
Rutsiro	.006	.271	.000	1	.983	1.006	.591	1.711
Rubavu	.768	.242	10.040	1	.002	2.155*	1.340	3.466
Nyabihu	.924	.243	14.444	1	<.001	2.519*	1.564	4.057
Ngororero	.869	.248	12.305	1	<.001	2.385*	1.467	3.876
Rusizi	.264	.261	1.027	1	.311	1.303	.781	2.172
Nyamasheke	.695	.246	7.976	1	.005	2.004*	1.237	3.247
Rurindo	.415	.274	2.285	1	.131	1.514	.884	2.593
Gakenke	.569	.264	4.662	1	.031	1.767*	1.054	2.962
Musanze	.558	.252	4.892	1	.027	1.747*	1.066	2.865
Burera	-.006	.280	.001	1	.982	.994	.574	1.720
Gicumbi	.729	.256	8.106	1	.004	2.073*	1.255	3.424
Rwamagana	-.691	.356	3.768	1	.052	.501	.249	1.007
Nyagatare	.423	.254	2.768	1	.096	1.527	.927	2.514
Gatsibo	-.674	.338	3.979	1	.046	.510*	.263	.988
Kayonza	.441	.251	3.081	1	.079	1.554	.950	2.544
Kirehe	.474	.261	3.297	1	.069	1.607	.963	2.682
Ngoma	-.876	.366	5.733	1	.017	.416*	.203	.853
Bugesera	.504	.251	4.046	1	.044	1.656*	1.013	2.708
Regions								
Southern	.203	.126	2.597	1	.107	1.226	.957	1.570
Western	.549	.120	20.858	1	<.001	1.732*	1.368	2.193
Northern	.403	.131	9.434	1	.002	1.496*	1.157	1.934
Eastern	.064	.127	.255	1	.614	1.066	.831	1.369
Urban-Rural								
Rural	.304	.085	12.712	1	<.001	1.355*	1.147	1.601

*. Statistically significant at the .05 level.

Figure 2

Variation of Diarrhea in Space Across Districts and Regions Between 2010-2020



Discussion

Interpretation

The study results responded to Research Question 1 and confirmed Hypothesis 1 that there is no significant variation of diarrhea among children under 5 years old. Hypothesis 2 was not confirmed by the study results that there is no significant variation in space of diarrhea among children under 5 years old in Rwanda between 2010-2020. Though diarrhea did not vary in time between 2010-2020, it did vary in space across communities/ districts, regions, and urban-rural areas in Rwanda (Tables 4, 5, and 6). Some districts show moderate decreasing diarrhea prevalence in 2015 which increased back again to their prevalence of 2010 in 2020 making no difference in prevalence of diarrhea between 2010-2020 nationally (Table 3 & Figures 1 and 2). Indeed, some districts kept a consistently higher prevalence of diarrhea between 2010-2020. Only the districts of Gisagara, Ngoma, and Rwamagana show a relatively big drop in the prevalence of diarrhea between 2010-2020. The districts of Karongi, Musanze, Rubavu, Nyaruguru, Nyabihu, Ngororero, Nyamashake, and Gicubi show a relatively continuous increase in the prevalence of diarrhea between 2010-2020. The Western and Northern regions show a relatively higher prevalence of diarrhea in 2020 (Table 1 & Figure 2). Though no difference in 2010, there was noted an increasing difference in diarrhea prevalence between urban and rural areas in 2015 and 2020. Negesse et al. (2021) found a variation in time and space in Ethiopia between 2000-2026 and confirmed most of the variation was due to behavior change. Progressive efforts to improve policies as well as their progressive implementation and improvements in organizational change and

funding that took place since 2010 in Rwanda are evident (Ekane et al., 2020; Rwanda Ministry of Health, 2008,2010,2015, 2017 & 2018; Rwanda Ministry of Infrastructure, 2010&2016& 2016 & 2017&2019; USAID, 2015). However, the persistence of the high prevalence of diarrhea among children under 5 years old in time and space and the absence of predictability on the health effect of the diarrhea control interventions are still a problem. The variation of diarrhea across districts, regions, and urban-rural areas may be due to (1) the unevenly spatial distribution of diarrhea risk factors and/or (2) the irregularities in the design and implementation of diarrhea control interventions (Tareke et al., 2022; Sinharoy et al., 2017; Waterkeyn et al., 2020). To make a progressive significant reduction in diarrhea, it is compulsory to address the main key diarrhea risk factors. Adequate inputs, quality design, and consistent implementation of diarrhea control interventions constitute a cornerstone for ensured health effect over time (Sinharoy et al., 2017; Waterkeyn et al., 2020). Often, diarrhea risk factors are unevenly distributed across places of residence (communities, regions, urban-rural) and the efforts required in terms of inputs and implementation of control interventions may differ accordingly (Asare et al., 2022; Das et al., 2023; Elshabassi et al., 2023; Masanja et al., 2019; Odiyo et al., 2020; Tamene and Afework, 2021; Terefe et al., 2023). Area-specific diarrhea control interventions, universal coverage (reach), and consistent quality implementation of diarrhea control interventions are needed to address contextual and comprehensive socio-ecological risk factors for diarrhea (Durlak & DuPre, 2008; Golden & Earp, 2012). Further research activities are needed to assess the contextual key diarrhea risk factors and the existing gap in the design and implementation of diarrhea

control intervention to conceptualize an integrated dynamical model that can be applied to communities, regions, and urban-rural areas to maximize the uptake and health outcomes of diarrhea control interventions in Rwanda (Glanz & Bishop, 2010; Mansnerus, 2014; Okoyo et al., 2021).

Limitations

The study was limited to secondary data analysis and interpretation. The variables used in the study were defined in the context of Rwanda Demographic Health Surveys. I relied on the information provided by the survey respondents irrespective of their intent other than the survey purpose.

Implications

There is a need to assess and understand local diarrhea risk factors to address them. Area-specific tailored diarrhea control interventions and the coverage, quality, and consistency of their implementation are required to ensure reduced diarrhea among children under 5 years old in Rwanda. A contextual and socio-ecological model-based approach to assess diarrhea risk factors and design adapted diarrhea control interventions is needed to produce area-specific diarrhea control interventions in Rwanda.

Recommendation

Further research activities are needed to assess the local-contextual key diarrhea risk factors and the existing gap in the design and implementation of diarrhea control intervention.

Conclusion

The progressive policy, organization, and financial efforts to significantly reduce diarrhea among children under 5 years old in Rwanda since 2010 do not show significant effect on the national prevalence of diarrhea among children under 5 years old between 2010-2020. The prevalence of diarrhea among children under 5 years old varies across districts, regions, and urban-rural areas between 2010-2020. Some districts of the Western region, Northern, and Southern regions are at higher risk of diarrhea with the Western region being consistently at higher risk of diarrhea among children under 5 years old between 2010-2020. According to this study's results, the effect of existing control interventions on diarrhea is limted between 2010-2020. There is a need to (a) assess and understand local diarrhea risk factors and (b) improve the quality design and the implementation of ongoing interventions. Area-specific tailored diarrhea control interventions and their effective implementation are required to ensure reduced diarrhea among children under 5 years old in time and across various places of residence in Rwanda.

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Manuscript 2 Title: Influence of Mothers' Social Status on Diarrhea Between 2010-2020 in Rwanda

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Outlet for Manuscript

The findings of this research study helped to describe mothers' social characteristics related diarrhea risk factors and their influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda. The study results constitute a basis for researchers and policy implementers/communities respectively for (a) further research on promoting mothers' social status in relation to increasing their capability and (b) the design and implementation/monitoring of mothers-related interventions to maximize the reduction of diarrhea among children under 5 years old in Rwanda.

Abstract

Mothers' empowerment to provide adequate care to protect and prevent children from contracting diarrheal diseases is of paramount importance. I conducted this cross-sectional study to assess the influence of mothers' education, employment, and exposure to domestic violence on diarrhea among children under 5 years old using secondary data from 2010, 2015, and 2020 Rwanda Demographic Health Surveys. I used stratified descriptive statistics, pairwise comparisons, and logistic regression designs to assess (a) the prevalence of mothers per social characteristics (domestic violence, education level, and employment status), (b) its variation over time, and (c) the influence of mothers' social characteristics on diarrhea among children under 5 years old between 2010-2020 in the context of Rwanda. According to the study findings, children whose mothers have (a) no education, (b) primary education, and (c) secondary education are 3.3 times, 2.8 times, and 2.4 times likely to have diarrhea respectively compared to those whose mothers have higher education. Regarding domestic violence, children whose mothers acknowledge (a) no decision of their own earnings, (b) no decision on their own healthcare, and (c) wife beating are 1.3 times, 1.2 times, and 1.4 times likely to have diarrhea than those whose mothers do not acknowledge domestic violence respectively. The findings of this study show the importance of considering the mother-related diarrhea risk factors and mother-related interventions in the control of diarrhea in children under 5 years old to ensure significant health effect.

Introduction

Children under 5 years old are vulnerable to diarrhea diseases due to their immune system still building up and their individual susceptibility. They therefore need adequate care with a healthy environment and practices from their respective mothers/caretakers to prevent them ingestion of pathogens that would cause diarrhea diseases. Mothers/caretakers are not always able to provide adequate care with healthy feeding, playing and interactive environments and health behaviors/ practices as needed to protect and prevent children from contracting diarrheal diseases. To achieve this, the mother/caretaker must ensure the child is (a) vaccinated, (b) adequately fed with healthy diet and appropriate feeding practice and frequency, and (c) provided a healthy environment. The mother/caretaker must ensure healthy practice (hand washing, child's feeding ...) and child's healthy environment for the child survival and development without diarrhea. However, the history of domestic violence, the level of education and the employment status of mothers/caretakers can interfere with or inhibit the care needed to (a) prevent the children's ingestion of pathogens, (b) strengthen the children's immunity system, and (c) reduce the children's vulnerability to diarrheal diseases. The research findings of Habtu et al. (2017) conducted in one district of Rwanda (Nyarugenge) and Negesse et al. (2021) in Ethiopia show the high prevalence and the variation of diarrhea among children under 5 years old was associated with the experience of domestic violence, the employment status, and the education level of mothers/caretakers. I felt the need for better understanding of these individual risk factors of mothers/caretakers for appropriate and specific strategies for prevention and reduction

of diarrhea in children under 5 years old in Rwanda. The research problem of the present study consisted of the influence of domestic violence, the level of education and the employment status of mothers and diarrhea among children under 5 years old in Rwanda between 2010-2020.

Literature Review

Diarrhea is transmitted through ingestion of pathogens and constitutes a burden to public health worldwide and in Rwanda especially among children under 5 years old. The mothers/caretakers of children are responsible of boosting the immune system of children, preventing them the ingestion of pathogens and other diseases through healthy behaviors/practices, healthy children's environment, and adequate healthcare. However, the research findings of Melese et al. (2019), Negesse et al. (2021), Nguyen et al. (2021), Wasonga et al. (2016) and WHO (2017) show individual factors in mothers/caretakers constitute risk factors of diarrhea among children under 5 years old. The history of domestic violence, the level of education, and the employment status of mothers/caretakers of children have influence on diarrhea among children under 5 years old.

Mothers' Experience of Domestic Violence

Domestic violence comprises several different forms of abusive behavior including control, physical abuse, sexual abuse, emotional abuse & intimidation, isolation, verbal abuse (coercion, threats, & blame), using male privilege, and economic abuse. Each of these forms has its own devastating consequences with potential short time higher risk and/ or long-term destruction of personhood, performance, and health of

victims and their dependents. Research findings indicated that children whose mothers experienced physical abuse (*aOR*: 1.34, 95% CI: 1.21–1.49), emotional abuse (*aOR*: 1.64, 95% CI: 1.45–1.86), sexual abuse (*aOR*: 1.30, 95% CI: 1.07–1.59) or all forms of violence (*aOR*: 2.08, 95% CI: 1.74–2.46) were more likely to have diarrhea than those who did not encounter any spousal violence in India (Pintu and Dinabandhu, 2020). A study conducted using Demographic Health Surveys from 25 Sub-Saharan African countries revealed a 34% reduction in diarrhea among children whose mothers disagreed with wife-beating compared to children whose mothers agreed with wife-beating (Zegeye et al., 2021). The research findings of Bahati et al. (2021), Fagbamigbe et al. (2021), and Pintu and Dinabandhu (2020 & 2021) indicated that women's exposure to physical violence, Intimate Partner Violence, psychological violence, and sexual violence by their partners was significantly associated with a lower likelihood of adequate healthcare utilization. In Rwanda, the study conducted by Bahati et al. (2021) showed that among married women living with their partners with at least one child aged 5 years or under (N = 5116), 17% of them reported physical violence, 22.8% reported psychological violence, and 9.2% reported sexual violence. On a national scale, the Rwanda Demographic Health survey of 2020 reported that among women aged 15-49, 37% have experienced physical violence, 23% have ever experienced sexual violence, and 46% of ever-married women have experienced spousal physical, sexual, or emotional violence. The research findings support that addressing the issue of domestic violence would improve mothers' performance in childcare through the adoption of safe behaviors and healthcare services (Bahati et al. 2021; Fagbamigbe et al., 2021; and Pintu and Dinabandhu, 2020 & 2021).

Though there is a high rate of domestic violence in Rwanda with a statistically significant likelihood of lower utilization of healthcare services among victims, there was no study yet done, at the time of the present study, to assess the influence of mothers' domestic violence in its various forms on diarrhea among children under 5 years old. This study aimed to assess the influence of domestic violence of mothers on diarrhea among children under 5 years old between 2005-2020 in Rwanda. The selected subset variables of domestic violence against mothers used in the data analysis included (a) the control on the earnings of the mother: the mother has no final say on her own earnings, (b) the control on the healthcare of the mother: the mother has no final say on her own healthcare, and (c) the acknowledgement of wife beating (wife beating for any reason) with values [Yes, No] in all cases.

Education Level of Mothers

Mother's level of education has been found associated with health status in children under 5 years old. The research study by Lawrence et al. (2020) indicated that children whose mothers had not completed high school education (*OR* = 3.84 95% CI: 3.62, 4.07), high school diploma (*OR* = 2.57 95% CI: 2.44-2.70), or college (*OR* = 1.90 95% CI: 1.80, 2.00) had worse reported health status compared to children whose mothers obtained their college degree. According to research findings the prevalence of diarrhea in 2025 was 5.163 times and 3.76 times for children whose mothers never attended school compared to those who attended a tertiary level of education in Rwanda nationally and in Nyarugenge district respectively (Habtu et al., 2017; Umuhoza et al., 2021). Indeed, maternal education has a positive effect on childcare with increased

prevention of child morbidity and mortality. This may be due to (a) more skills gained with a potential continuous skills building, (b) socialization, interaction with health bureaucracies, and other sources of beneficial information leading to increased access to information on the duration of breastfeeding, proper childcare, utilization of healthcare services, (c) progressive behavior change, and (d) potential increase in equitable gender attitude and autonomy (Lawrence et al., 2020; Mensch et al., 2019). The research findings of Melese et al. (2019) indicated that children with mothers/caretakers with no education are at higher risk of diarrhea (*aOR* = 3.97, 95% CI [1.60, 8.916]) compared with children with mothers/caretakers who attend tertiary education in Southern Ethiopia. Hbatu et al. (2017) confirmed higher risk of diarrhea among children whose caretakers have (a) no education level (*aOR* = 3.76; 95%CI [1.26-11.24], p=0.018) and (b) primary education level (*aOR* = 2.94; 95%CI [1.04-8.28], p=0.042) compared to those with tertiary education level in Nyarugenge district of Rwanda. In Rwanda, at the time of our study, it was not known what the influence of a mother's education level on child diarrhea is and how it varied between 2005-2020 nationally and across communities in Rwanda. This study intended to assess the influence of education level of the mother on diarrhea in children under 5 years old between 2005-2020 in Rwanda. The research findings were intended to be a contribution to addressing this key risk factor to improve the capacity of households particularly and the community, in general, to comprehensively reduce diarrhea. Indeed, this risk factor can be a proxy indicator for other aspects in terms of knowledge, understanding/ behavior change, and skills for adequate childcare (Modern et al., 2020; Ramanathan & Vijayan, 2019). The variable

education level of the mother with values no education, primary education, secondary education, and tertiary education were used in the data analysis as indicated in the RDHS dataset.

Employment Status of Mothers

According to the findings of analysis of DHS from 34 sub-Saharan countries, the prevalence of diarrhea was greater (*AOR* = 1.12, 95% [1.10–1.15]) in working mothers compared to not working mothers (Demissie et al., 2021). The study of Sinmegn et al. (2014) in Ethiopia indicated that children whose mothers had work were 2 times more likely to have diarrhea compared to children whose mothers were not working (*COR* = 1.76, 95% CI [1.28, 2.43]). The study conducted by Agegnehu et al. (2019) indicated that child diarrhea prevention practices are 3.92 times higher among housewives compared to working mothers (*OR* = 3.92, 95% [1.59-9.66]). The research findings of Pintu & Dinabandhu (2020) in India indicate that maternal exposure to emotional, physical and sexual violence significantly increased the likelihood of diarrhea among children under-5 years old with (*aOR* = 1.64, 95% CI[1.45–1.86]) for children whose mothers experienced emotional sexual violence, (*aOR* = 1.34, 95% CI[1.21–1.49]) for children whose mothers experienced physical violence, and (*aOR* = 1.30, 95% CI[1.07–1.59]) for children whose mothers experienced sexual violence (*aOR*: 2.08, 95% CI[1.74–2.46]) for children whose mothers experienced all forms of violence than those who did not encounter any spousal violence, $p < 0.01$. The same author reports a prevalence of diarrhea of 2.8 times in children from households with domestic violence compared to those from households with no domestic violence in India. A study conducted using Demographic Health

surveys from 25 sub-Saharan Africa revealed a 34% reduction of diarrhea among children whose mothers disagreed with wife beating compared to children whose mothers agreed with wife-beating (Zegeye et al., 2021). According to Negesse et al. (2021) and Solomon et al. (2020), the risk of diarrhea was respectively 14% lesser for children with mothers who do not work compared to children whose mothers are working and 3% lesser (*OR* = 0.97, 95%CI[0.71–1.32]) for children whose mothers are housewife compared to miscellaneous in their respective studies. In Rwanda, it is not known, at the time of our study, how the employment status of mothers influenced diarrhea with time and across communities between 2005-2020. In the present study, I assessed the influence of mothers' employment status on child diarrhea between 2005-2020. The variable is employment status with values [currently employed, not employed].

Significance of the Study

The results of this research study on the influence of domestic violence, education level and employment status of mothers on diarrhea among children under 5 years old between 2010-2020 across communities in Rwanda constitute a contribution to (a) better understand the level of influence of these mother-related risk factors on diarrhea and (b) identify the high-risk areas which are useful to guide the design and the implementation of appropriate and specific interventions to address the identified risk factors across communities in Rwanda for maximum prevention and reduction of diarrhea in children under 5 years old in Rwanda. The theoretical framework for this research consisted of the socio-ecological model which was used to connect individual characteristics of mothers with children's health. Indeed, these individual characteristics vary across households and

communities as predicators of diarrhea and their influence on diarrhea too. Addressing these individual risk factors required the socio-ecological approach through (a) ensuring appropriate and specific knowledge and practice of mothers and (b) strengthening empowerment of mothers and social support for a maximum adoption of healthy practices and a healthy child's environment (Ahsan et al., 2017; Glanz & Bishop, 2010; National Academies of Sciences, Engineering, and Medicine, 2001; Nguyen et al., 2021; Pinzón-Rondón et al., 2015). With the findings of this research, I intended to (a) map the areas of influence of domestic violence, education level, and employment status of mothers and (b) guide area- and risk-specific improvements in the design and implementation of interventions for maximum reduction of diarrhea among children under 5 years old in Rwanda.

Purpose of the Study, Research Questions, and Hypotheses

The purpose of this research study was to assess the influence of mother's own history of domestic violence, education level, and employment status on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Research Question 1: What is the influence of domestic violence against mothers on diarrhea among children under 5 years old between 2010-2020 in Rwanda?

$H_0$1: There is no influence of domestic violence against mothers on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_1$1: There is an influence of domestic violence against mothers on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Research Question 2: Does the mother's education level have influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda?

$H_0$2: The mother's education level does not have influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_1$2: The mother's education level has influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Research Question 3: What is the level of influence of mother' employment status on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_0$3: The mother' employment status does not have influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

$H_1$3: The mother' employment status has influence on diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Methods

Data Collection and the Study Participants

In this study, I used secondary data from the National Institute of Statistics of Rwanda and the study participants are children under 5 years old and their mothers in Rwanda with a sample of 8,418, 7,474, and 7,755 for the 2010, 2015, and 2020 surveys respectively.

Variables

The variables for this research study consisted of the prevalence of diarrhea among children under 5 years old as a dependent variable and the independent variables included (a) domestic violence against mothers whose subset variables are the control on

the earnings of the mother, the mother has no final say on her own earnings with values [No, Yes], the control on the healthcare of the mother, the mother has no final say on her own healthcare with values [No, Yes], and the experience of wife beating (for any reason) with values [No, Yes], (b) mothers' education level with values [no education, primary education, secondary education, and tertiary education], and (c) mothers' employment status with values [employed, or not employed] (Negesse et al., 2021; Nshimiyimana and Zhou, 2022; Saha et al., 2022; Warner, 2013).

Design and Analysis

I used stratified descriptive statistics, pairwise comparisons, and logistic regression to assess (a) the prevalence of mothers per social characteristics (domestic violence, education level, and employment status), (b) their variation over time, and (c) their influence of on diarrhea among children under 5 years old between 2010-2020 in the context of Rwanda. Mean difference (μ) and effect size (F) were used to report the findings on the variation of mothers' social characteristics over time with a *p*-value at the significance level of <0.05 and 95% confidence interval while Odds ratio [OR] was used to report the findings on the influence of mothers' social characteristics on diarrhea among children under 5 years old with a *p*-value at significance level of <0.05 and 95% confidence interval.

Results

The study used secondary data from the National Institute of Statistics of Rwanda and collected datasets on (a) child's health and (b) child-mother's social characteristics of the Demographic Health Surveys 2010, 2015, and 2020. Data analysis and interpretation

of results followed data cleaning including re-coding of some variables and removal of missing data.

Descriptive Analysis

Descriptive Statistics analysis was used to compute the prevalence and the average of Mothers (a) with no education, primary, secondary, and higher education, (b) currently working or not (status of employment), and (c) victims of domestic violence per community, region, and urban-rural areas (Table 1, 2, and 3).

Table 1

Education Level of Mothers in % Between 2005-2020

	2010				2015				2020			
Community (District)	No education	Primary	Secondary	Higher	No education	Primary	Secondary	Higher	No education	Primary	Secondary	Higher
Nyarugenge	5.4	55.7	31.2	7.7	2.6	62.7	30.7	3.9	4.3	56.5	30.1	9.1
Gasabo	9.0	61.1	22.2	7.7	6.4	63.8	22.4	7.4	6.1	47.2	33.3	13.3
Kicukiro	7.9	53.3	28.0	10.9	3.5	52.5	28.8	15.2	3.6	32.0	38.4	26.0
Nyanza	12.7	79.1	7.8	0.4	14.2	78.0	5.2	2.6	9.8	67.9	18.8	3.6
Gisagara	20.3	74.2	5.6	0.0	17.4	76.7	5.9	0.0	15.4	70.5	10.3	3.8
Nyarubuye	22.8	68.9	7.6	0.7	20.9	68.6	10.1	0.4	19.8	70.6	8.1	1.6
Huye	9.2	82.3	8.5	0.0	10.0	71.9	10.0	8.1	7.6	69.7	19.7	3.0
Nyamagabe	22.1	73.0	4.6	0.4	20.6	71.1	5.5	2.8	12.8	67.8	15.4	4.0
Ruhango	18.7	77.0	4.3	0.0	8.7	75.7	13.1	2.4	11.0	70.5	15.0	3.5
Muhanga	11.6	79.9	8.0	0.4	6.8	79.5	11.0	2.7	6.8	73.9	15.9	3.4
Kamonyi	14.3	77.9	7.4	0.4	6.8	75.6	13.7	3.8	7.9	68.8	17.3	5.9
Karongi	19.6	72.7	7.3	0.4	15.3	69.3	14.9	0.5	12.5	64.6	17.5	5.4
Rutsiro	24.3	71.6	4.2	0.0	23.1	68.6	7.2	1.1	19.8	67.3	10.9	2.0
Rubavu	39.0	55.9	5.2	0.0	24.6	66.4	6.6	2.3	16.6	57.7	19.5	6.2
Nyabihu	24.3	70.0	5.3	0.3	21.2	70.3	7.6	0.8	10.5	64.9	23.2	1.4
Ngororero	28.8	66.7	4.2	0.3	29.0	59.3	7.3	4.4	18.0	70.3	11.3	0.4
Rusizi	17.9	76.1	5.3	0.7	18.7	76.5	4.5	0.3	12.2	71.8	11.2	4.8
Nyamashek e	20.2	75.7	3.8	0.3	10.7	81.9	6.7	0.6	12.6	69.0	16.3	2.0
Rurindo	13.1	82.4	4.5	0.0	9.6	79.0	10.5	0.9	5.7	75.9	13.7	4.7
Gakenke	16.2	77.3	6.1	0.4	8.1	84.4	6.9	0.6	9.7	70.9	15.9	3.5
Musanze	18.3	76.0	5.3	0.4	16.3	72.8	8.4	2.5	9.9	59.2	25.2	5.7
Burera	23.4	72.2	4.4	0.0	13.0	72.6	13.0	1.3	16.8	59.7	19.0	4.5
Gicumbi	21.9	74.6	3.5	0.0	14.4	74.4	8.8	2.3	8.1	76.2	14.9	0.9
Rwamagana	14.5	72.1	13.0	0.4	5.2	79.5	13.1	2.2	5.6	63.0	25.0	6.5
Nyagatare	24.8	70.9	4.3	0.0	22.8	64.9	10.4	1.9	10.5	71.3	16.9	1.4
Gatsibo	19.1	73.2	7.0	0.6	14.2	74.3	11.2	0.4	9.7	65.7	20.6	4.0
Kayonza	18.8	73.5	6.5	1.2	14.5	73.7	10.3	1.5	9.3	67.8	19.9	2.9
Kirehe	18.3	75.7	5.6	0.4	19.7	71.3	8.6	0.4	15.9	66.3	16.3	1.6
Ngoma	18.1	76.9	5.1	0.0	15.3	73.3	9.3	2.1	13.1	65.3	18.6	3.0
Bugesera	20.3	72.7	7.0	0.0	13.6	69.4	14.0	3.1	12.6	69.1	14.0	4.3
Region												
Kigali City	7.5	56.8	27.0	8.7	4.2	60.1	27.2	8.5	4.8	45.4	33.9	15.9
Southern	16.7	76.3	6.7	0.3	13.4	74.6	9.2	2.8	11.7	69.9	14.8	3.6
Western	24.9	69.8	5.0	0.3	20.2	70.8	7.6	1.4	14.6	66.4	15.7	3.2
Northern	18.7	76.3	4.8	0.2	12.4	76.3	9.7	1.5	10.3	67.6	18.1	3.9
Eastern	19.3	73.5	6.9	0.3	14.9	72.4	11.0	1.7	11.0	67.2	18.5	3.3

Community (District)	2010				2015				2020			
	No education	Primary	Secondary	Higher	No education	Primary	Secondary	Higher	No education	Primary	Secondary	Higher
Urban/rural												
Urban	8.0	60.1	24.6	7.4	7.3	57.1	25.3	10.3	5.0	45.3	32.6	17.1
Rural	20.3	73.7	5.7	0.2	16.2	75.7	7.5	0.5	12.9	70.4	15.0	1.7
Total average	18.6	71.9	8.3	1.2	14.3	71.6	11.4	2.7	11.2	65.1	18.7	4.9
Total sample	8, 418				7, 474				7, 755			

Table 2

Employment Status of Mothers in % Between 2005-2020

	2010		2015		2020	
Community (District)	Not Employed	Employed	Not Employed	Employed	Not Employed	Employed
Nyarugenge	44.3	55.7	33.3	66.7	51.1	48.9
Gasabo	37.7	62.3	23.7	76.3	39.7	60.3
Kicukiro	33.2	66.8	36.2	63.8	43.1	56.9
Nyanza	9.0	91.0	1.7	98.3	16.1	83.9
Gisagara	24.5	75.5	11.5	88.5	7.3	92.7
Nyarubuye	8.3	91.7	8.9	91.1	6.9	93.1
Huye	4.3	95.7	27.6	72.4	40.9	59.1
Nyamagabe	28.1	71.9	7.8	92.2	54.6	45.4
Ruhango	0.4	99.6	2.9	97.1	42.7	57.3
Muhanga	18.8	81.3	5.5	94.5	20.3	79.7
Kamonyi	9.7	90.3	9.4	90.6	39.6	60.4
Karongi	1.2	98.8	3.3	96.7	23.7	76.3
Rutsiro	5.8	94.2	3.8	96.2	22.8	77.2
Rubavu	39.0	61.0	52.5	47.5	18.2	81.8
Nyabihu	3.0	97.0	19.1	80.9	15.6	84.4
Ngororero	23.3	76.7	4.8	95.2	30.1	69.9
Rusizi	57.1	42.9	5.5	94.5	35.4	64.6
Nyamasheke	5.8	94.2	8.0	92.0	24.1	75.9
Rurindo	64.3	35.7	20.5	79.5	14.6	85.4
Gakenke	31.4	68.6	5.8	94.2	4.4	95.6
Musanze	9.2	90.8	18.8	81.2	24.8	75.2
Burera	0.8	99.2	9.6	90.4	38.8	61.2
Gicumbi	70.0	30.0	6.5	93.5	15.7	84.3
Rwamagana	1.4	98.6	10.1	89.9	29.6	70.4
Nyagatare	3.4	96.6	5.8	94.2	13.5	86.5
Gatsibo	5.7	94.3	47.0	53.0	9.7	90.3
Kayonza	36.5	63.5	11.5	88.5	12.5	87.5
Kirehe	13.7	86.3	4.5	95.5	10.3	89.7
Ngoma	28.2	71.8	5.0	95.0	26.3	73.7
Bugesera	4.5	95.5	5.8	94.2	17.9	82.1
Region						
Kigali City	38.3	61.7	30.7	69.3	44.2	55.8
Southern	13.1	86.9	9.5	90.5	28.0	72.0
Western	19.5	80.5	14.6	85.4	24.2	75.8
Northern	34.4	65.6	12.4	87.6	20.6	79.4
Eastern	12.6	87.4	12.9	87.1	16.6	83.4

Community (District)	2010		2015		2020	
	Not Employed	Employed	Not Employed	Employed	Not Employed	Employed
Urban/rural						
Urban	33.4	66.6	26.4	73.6	35.4	64.6
Rural	18.5	81.5	11.2	88.8	22.2	77.8
Total average	20.5	79.5	14.5	85.5	25.0	75.0
Total sample	8, 418		7, 474		7, 755	

Table 3

Prevalence of Domestic Violence Against Mothers in % Between 2005-2020

	2010			2015			2020		
Community (District)	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare
Nyarugenge	31.9	3.3	7.9	22.2	4.5	9.2	32.6	13.0	29.7
Gasabo	49.1	12.4	30.2	9.3	10.5	16.4	25.6	4.1	20.2
Kicukiro	41.8	11.3	18.9	3.1	10.3	4.3	22.8	2.1	5.5
Nyanza	43.4	11.3	21.3	58.2	21.9	22.8	76.8	20.0	14.9
Gisagara	71.9	5.5	30.3	44.3	25.9	17.1	80.8	1.9	6.7
Nyarubuye	57.0	9.3	20.1	54.3	6.8	15.7	45.2	10.4	29.1
Huye	52.8	10.2	17.6	56.6	8.0	18.8	61.6	4.9	10.8
Nyamagabe	58.6	18.5	32.8	58.3	16.7	20.5	75.3	25.0	20.0
Ruhango	33.9	5.7	17.2	14.1	3.8	14.1	67.8	3.5	4.7
Muhanga	79.0	4.9	48.1	58.9	10.3	23.5	44.0	4.3	11.1
Kamonyi	58.5	22.2	41.0	47.4	17.1	17.1	29.2	7.2	11.1
Karongi	45.4	12.3	11.3	68.4	13.1	29.9	54.1	19.4	28.4
Rutsiro	43.8	16.5	22.3	59.1	15.9	9.0	81.5	10.2	7.2
Rubavu	80.3	30.1	41.9	45.5	3.2	5.1	38.8	8.8	19.6
Nyabihu	67.0	7.1	27.7	32.6	3.0	2.9	69.2	10.5	45.4
Ngororero	69.1	8.7	21.5	52.4	10.6	26.6	59.0	7.9	13.4
Rusizi	70.1	15.5	36.0	45.7	12.4	42.9	58.2	22.7	43.8
Nyamasheke	88.7	13.9	15.2	58.0	15.5	29.9	56.5	4.8	8.9
Rurindo	47.5	9.1	21.4	68.5	2.4	4.9	61.8	5.6	15.9
Gakenke	70.4	22.4	29.9	45.7	0.0	9.3	44.9	5.6	33.7
Musanze	80.5	17.8	29.2	62.9	14.9	18.4	66.3	7.8	20.2
Burera	88.5	17.4	59.1	41.3	10.3	28.5	51.9	6.1	6.9
Gicumbi	48.5	7.6	13.4	42.8	32.5	20.2	65.5	17.3	27.6
Rwamagana	56.5	21.6	17.3	22.0	6.7	0.5	24.5	1.1	6.2
Nyagatare	31.9	8.1	2.8	49.8	8.9	20.0	55.1	11.0	29.2
Gatsibo	70.4	42.7	53.1	32.1	25.4	8.4	14.5	20.2	10.4
Kayonza	74.6	26.7	38.7	35.1	11.9	9.6	44.4	4.3	7.1
Kirehe	61.3	15.6	13.5	15.2	0.0	1.4	57.5	8.8	28.9
Ngoma	67.5	23.8	21.7	17.4	24.1	15.2	49.6	10.6	13.7
Bugesera	59.4	20.7	42.1	38.4	11.7	27.1	46.5	12.0	20.2
Region									
Kigali City	41.1	9.4	19.1	12.0	8.6	10.5	26.8	5.9	18.6
Southern	57.2	10.6	28.2	49.3	13.3	18.6	60.6	9.1	14.1
Western	66.4	14.1	25.4	51.5	11.0	21.2	59.6	11.1	23.6

Community (District)	2010			2015			2020		
	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare	Wife Beating for any reason	No decision on own earnings	No decision on own healthcare
Northern	67.6	15.3	30.9	52.3	14.0	16.8	58.3	7.8	20.3
Eastern	59.6	24.3	26.8	29.9	13.7	11.9	42.6	9.9	17.1
Urban/rural									
Urban	43.5	10.2	17.4	26.4	7.6	12.3	33.1	7.1	14.8
Rural	62.4	16.6	28.0	45.3	13.8	17.6	56.6	9.9	19.9
Total average	59.8	15.7	26.6	41.1	12.3	16.5	51.6	9.2	18.8
Total sample	8, 418			7, 474			7, 755		

Logistic Regression Analysis

Using the dataset of child's health and child mother's sociodemographic characteristics, the binary logistic regression analysis was used to assess the influence of the mother's highest educational level attained, employment status, and the status of being a victim of domestic violence or not on diarrhea among children among children under 5 years old. Table 4 shows the prevalence of diarrhea was higher (*OR* = 3.060, 95%CI[1.112;8.420], *p* = 0.030), (*OR* = 3.965, 95%CI[1.445;10.804], *p* = 0.007), (*OR* = 3.540, 95%CI[1.271;9.862], *p* = 0.016) respectively among children whose mothers attained no education, primary education, and secondary education compared to those whose mothers attained higher education in 2010. Reference made to mothers who are not employed, the prevalence of diarrhea (*OR* = 0.840, 95%CI[0.722;0.976], *p* = 0.023) among children whose mothers are employed is lower. The prevalence of diarrhea among children whose mothers have no decision on their own earnings (*OR* = 1.102, 95%CI[0.867;1.400], *p* = 0.428) does not significantly differ from the diarrhea prevalence among those whose mothers have a decision on their own earnings (reference)

in 2010. Compared to the prevalence of diarrhea among children whose mothers have a decision on their own healthcare, the prevalence of diarrhea among children whose mothers have no decision on their own healthcare is significantly higher (*OR* = 1.306, 95%[1.123;1.519], $p < 0.001$). The prevalence of diarrhea among children whose mothers acknowledge wife beating for any reason (*OR* = 1.282, 95%CI[1.124;1.463], $p < 0.001$) was higher compared to the prevalence of diarrhea among children whose mothers have decision of their healthcare.

Table 4

Influence of Mother's Characteristics on Diarrhea in 2010

	Diarrhea							
Mother's characteristics	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. Lower	95% C.I. Upper
No education	1.119	.516	4.691	1	.030	3.060*	1.112	8.420
Primary education	1.377	.511	7.254	1	.007	3.965*	1.455	10.804
Secondary education	1.264	.523	5.850	1	.016	3.540*	1.271	9.862
Employed	-.175	.077	5.157	1	.023	.840*	.722	.976
No decision on own earnings	.097	.122	.629	1	.428	1.102	.867	1.400
No decision on own healthcare	.267	.077	12.041	1	<.001	1.306*	1.123	1.519
Acknowledge wife beating for any reason	.248	.067	13.644	1	<.001	1.282*	1.124	1.463

*. The mean difference is significant at the .05 level.

According to the study results in Table 5, the prevalence of diarrhea is higher respectively among children whose mothers have no education (*OR* = 6.102, 95%CI[2.469;15.081], $p < 0.001$), have primary education (*OR* = 5.539, 95%[2.271;13.508], $p < 0.001$), have secondary education (*OR* = 4.350, 95%[1.742;10.865], $p = 0.002$) compared to those whose mothers have higher education

in 2015. The prevalence of diarrhea among children whose mothers have no decision on their own healthcare (*OR* = 1.339, 95%[1.100;1.631], $p = 0.004$) and acknowledge wife beating for any reason (*OR* = 1.695, 95%[1.474;1.949], $p < 0.001$) is higher than those whose mothers have a decision on their healthcare and don't acknowledge wife beating for any reason respectively. There is no significant difference between the prevalence of diarrhea among children whose mothers are employed or not and whose mothers have a decision on their own earnings or not.

Table 5

Influence of Mother's Characteristics on Diarrhea in 2015

	Diarrhea							
Mother's characteristics	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. Lower	95% C.I. Upper
No education	1.809	.462	15.347	1	<.001	6.102*	2.469	15.081
Primary education	1.712	.455	14.166	1	<.001	5.539*	2.271	13.508
Secondary education	1.470	.467	9.912	1	.002	4.350*	1.742	10.865
Employed	.054	.102	.280	1	.597	1.056	.864	1.290
No decision on own earnings	.044	.151	.086	1	.769	1.045	.777	1.405
No decision on own healthcare	.292	.100	8.465	1	.004	1.339*	1.100	1.631
Acknowledge wife beating for any reason	.528	.071	54.920	1	<.001	1.695*	1.474	1.949

*. The mean difference is significant at the .05 level.

Table 6 shows that the prevalence of diarrhea among children whose mothers have no education (*OR* = 3.345, 95%CI[2.100;5.327], $p < 0.001$), have primary education (*OR* = 2.827, 95%[1.826;4.379], $p < 0.001$), and have secondary education (*OR* = 2.451, 95%[1.552;3.870], $p < 0.001$) is higher respectively compared to those whose mothers

have higher education in 2020. The prevalence of diarrhea among children whose mothers have no decision on their own earnings (*OR* = 1.380, 95%[1.029;1.853], p = 0.032), their own healthcare (*OR* = 1.253, 95%[1.055;1.490], p = 0.010), and acknowledge wife beating for any reason (*OR* = 1.422, 95%[1.250;1.619], $p < 0.001$) is higher than those whose mothers do not respectively. There is no significant difference between the prevalence of diarrhea among children whose mothers are employed or not.

Table 6

Influence of Mother's Characteristics on Diarrhea in 2020

	Diarrhea							
Mother's characteristics	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. Lower	95% C.I. Upper
No education	1.207	.237	25.865	1	<.001	3.345*	2.100	5.327
Primary education	1.039	.223	21.687	1	<.001	2.827*	1.826	4.379
Secondary education	.896	.233	14.792	1	<.001	2.451*	1.552	3.870
Employed	.057	.076	.571	1	.450	1.059	.913	1.229
No decision on own earnings	.322	.150	4.614	1	.032	1.380*	1.029	1.853
No decision on own healthcare	.226	.088	6.569	1	.010	1.253*	1.055	1.490
Acknowledge wife beating for any reason	.352	.066	28.523	1	<.001	1.422*	1.250	1.619

*. The mean difference is significant at the .05 level.

Repeated Measures Analysis

The prevalence data of mothers' characteristics calculated above, repeated measures analysis was conducted to assess the variation of mother's education level attained and the mother's status of being victim of domestic violence or not between 2010-2020. According to Table 7, there is a reduction of cases of mothers with no education (μ = 7.357, 95%CI[5.279;9.435], $p < 0.001$) and primary education (μ = 6.573,

95%CI[3.902;9.245], $p < 0.001$) while the cases of mothers with secondary ($\mu = 10.313$, 95%CI[8.293;12.334], $p < 0.001$) and higher education ($\mu = 3.613$, 95%CI[2.335;4.892], $p < 0.001$) increased between 2010-2020.

Table 7

Variation of Mother's Education Level Attained Between 2010-2020

(I) No Education	(J) No Education	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference	
					Lower Bound	Upper Bound
1	2	4.257*	.718	<.001	2.432	6.081
	3	7.357*	.818	<.001	5.279	9.435
2	1	-4.257*	.718	<.001	-6.081	-2.432
	3	3.100*	.764	.001	1.158	5.042
3	1	-7.357*	.818	<.001	-9.435	-5.279
	2	-3.100*	.764	.001	-5.042	-1.158
(I) Primary education	(J) Primary education	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference	
					Lower Bound	Upper Bound
1	2	.353	.838	1.000	-1.777	2.484
	3	6.573*	1.051	<.001	3.902	9.245
2	1	-.353	.838	1.000	-2.484	1.777
	3	6.220*	1.238	<.001	3.074	9.366
3	1	-6.573*	1.051	<.001	-9.245	-3.902
	2	-6.220*	1.238	<.001	-9.366	-3.074
(I) Secondary education	(J) Secondary education	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference	
					Lower Bound	Upper Bound
1	2	-3.097*	.527	<.001	-4.435	-1.758
	3	-10.313*	.795	<.001	-12.334	-8.293
2	1	3.097*	.527	<.001	1.758	4.435
	3	-7.217*	.851	<.001	-9.379	-5.054
3	1	10.313*	.795	<.001	8.293	12.334
	2	7.217*	.851	<.001	5.054	9.379
(I) Higher education	(J) Higher education	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference	
					Lower Bound	Upper Bound
1	2	-1.483*	.376	.001	-2.439	-.528
	3	-3.613*	.503	<.001	-4.892	-2.335
2	1	1.483*	.376	.001	.528	2.439
	3	-2.130*	.540	.001	-3.503	-.757
3	1	3.613*	.503	<.001	2.335	4.892
	2	2.130*	.540	.001	.757	3.503

*. The mean difference is significant at the .05 level.

Table 8 shows a reduction of cases of mothers acknowledging no decision on own earning (μ = 5.370, 95%CI[0.801;9.939], p = 0.017) between 2010 and 2020. For wife beating and no decision on own healthcare, there is no statistically significant difference between 2010 and 2020.

Table 8

Variation of Mother's Domestic Violence Status Between 2010-2020

					95% CI for Difference	
(I) Wife Beating	(J) Wife Beating	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
1	2	17.990*	3.953	<.001	7.945	28.035
	3	7.927	4.452	.256	-3.385	19.238
2	1	-17.990*	3.953	<.001	-28.035	-7.945
	3	-10.063*	3.311	.015	-18.475	-1.651
3	1	-7.927	4.452	.256	-19.238	3.385
	2	10.063*	3.311	.015	1.651	18.475
(I) No decision on own Earnings	(J) No decision on own Earnings	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference Lower Bound	Upper Bound
1	2	3.130	1.966	.367	-1.865	8.125
	3	5.370*	1.798	.017	.801	9.939
2	1	-3.130	1.966	.367	-8.125	1.865
	3	2.240	1.495	.434	-1.558	6.038
3	1	-5.370*	1.798	.017	-9.939	-.801
	2	-2.240	1.495	.434	-6.038	1.558
(I) No decision on own Healthcare	(J) No decision on own Healthcare	Mean Difference (I-J)	Std. Error	Sig.	95% CI for Difference Lower Bound	Upper Bound
1	2	10.473*	2.849	.003	3.233	17.713
	3	8.433	3.540	.072	-.561	17.428
2	1	-10.473*	2.849	.003	-17.713	-3.233
	3	-2.040	2.586	1.000	-8.610	4.530
3	1	-8.433	3.540	.072	-17.428	.561
	2	2.040	2.586	1.000	-4.530	8.610

*. The mean difference is significant at the .05 level.

Discussion

Interpretation

The study results show that the level of education attained by mothers has consistently had a significantly high influence on diarrhea among children under 5 years old in 2010, 2015, and 2020. The lower levels of education of mothers, the higher the prevalence of diarrhea. The higher the level of education of mothers, the lower the prevalence of diarrhea among children under 5 years old (Table 4,5,6). The domestic violence against mothers represented by mothers acknowledging (a) having no decision on their own earnings, (b) having no decision on their own healthcare, and (c) wife beating for any reason constitutes a significant predictor of diarrhea among children under 5 years old in 2010, 2015, and 2020 (Tables 4, 5, and 6). The findings of this study confirm the importance of knowledge, the availability, and the readiness of mothers to offer adequate care to children as previously published by Habtu et al. (2017), Pintu and Dinabandhu (2020), Umuhoza et al. (2021), and Zegeye et al. (2021) who confirmed the influence of mothers' literacy and status of being a victim of domestic violence or not on diarrhea among children under 5 years old. According to the study results, the existing programs for improving mother's health and wellbeing are promising and need continuous support for increased child's care and reduced diarrhea. Focus is more needed on poorly educated mothers to ensure a reduction of diarrhea among children under 5 years old. Health education and promotion programs must have strong social support, adoption, and monitoring strategies with appropriate indicators to ensure the education gap for mothers is compensated for improved child healthcare and reduced diarrhea

(Modern et al., 2020; Ramanathan & Vijayan, 2019). The level of understanding, willingness, and skills needed would be acquired through tailored community-based health education and promotion programs.

According to the study results, only the cases of mothers acknowledging no decision on own earning ($\mu = 5.370$, 95%CI[0.801;9.939], $p = 0.017$) between 2010 and 2020 reduced. For cases acknowledging wife beating and no decision on own healthcare, there is no statistically significant difference between 2010 and 2020 though a statistically significant decline was observed between 2010 and 2015 (table 8). Addressing domestic violence against mothers constitutes an aspect that needs continuous support to foster the reduction of diarrhea among children under 5 years old. The findings of this study show the importance of mother-related individual diarrhea risk factors in addition to other socioecological diarrhea risk factors. To ensure a significant reduction of diarrhea among children under 5 years old in Rwanda, the application of the socio-ecological model to (a) assess the related multi-level risk factors and (b) guide the design and the implementation of the control interventions constitutes a sine qua non condition.

Limitations

My study was limited to secondary data analysis and interpretation. The variables used in the study were defined in the context of Rwanda Demographic Health Surveys. I relied on the information provided by the survey respondents irrespective of their intent other than the survey purpose.

Implications

Based on the study findings, there is a need for more focus particularly on poorly educated mothers and domestic violence against mothers to ensure a significant reduction of diarrhea among children under 5 years old. Emphasis should be put on social support, health education and promotion programs to ensure the gap in education of mothers and the prevention of domestic violence against mothers is compensated for improved child healthcare by mothers and reduced diarrhea. The findings of this study show that it is essential to use the socioecological model to (a) assess comprehensively diarrhea risk factors and (b) guide the implementation of adequately designed control interventions.

Recommendation

Diarrhea control interventions must consider addressing the problem of low education of mothers and domestic violence against mothers among other risk factors in the design and implementation according to local needs to ensure a significant reduction of diarrhea among children under 5 years old.

Conclusion

The study findings showed that domestic violence against mothers and low education have a significant influence on diarrhea. According to the study findings, lower levels of education and mothers' acknowledgment of domestic violence are associated with increased diarrhea among children under 5 years old while higher levels of education and no acknowledgment of domestic violence for mothers are associated with lower diarrhea among children under 5 years old in Rwanda. Between 2010-2020, the study findings highlight a decline in the prevalence of lower levels of education and an

increase in the prevalence of higher levels of education of mothers. However, in terms of domestic violence, a decline was only observed in the cases of mothers acknowledging having no decision on their own earnings between 2010 and 2020. For cases acknowledging wife beating and no decision on own healthcare, there was no statistically significant difference between 2010 and 2020. The findings of this study show the importance of considering the mother-related individual diarrhea risk factors and existing mother-related programs to improve mothers' social status and well-being that are necessary to ensure increased childcare and reduced diarrhea.

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Manuscript 3 Title: Relationship Between Household Water Sanitation and Hygiene Behaviors and Diarrhea Between 2010-2020 in Rwanda

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Outlet for Manuscript

The findings of this research study helped to describe household WASH behavioral diarrhea risk factors and their relationship with diarrhea in time and in space across communities between 2010-2020 in Rwanda. The study results constitute a basis for researchers and policy implementers/communities for (a) further research on area-specific motivators and inhibitors of household WASH adoption sustainability and (b) the design/adaptation of existing interventions and implementation/monitoring of area-specific interventions to maximize the reduction of diarrhea in Rwanda respectively.

Abstract

Safe household WASH conditions are unconditional for child survival and development. I conducted this cross-sectional study to assess the relationship between household WASH behaviors and diarrhea among children under 5 years old between 2010-2020. I used secondary data from 2010, 2015, and 2020 Rwanda Demographic Health Surveys. I used descriptive statistics, pairwise comparisons, and linear regression designs to assess (a) the prevalence of WASH behaviors across communities, regions, and urban-rural areas (b) the variation of WASH behaviors over time and across communities, regions, and urban-rural areas, and (c) the relationship between household WASH behaviors and diarrhea. The study results did not find a statistically significant relationship between hand washing, water treatment, safe water storage, and use of clean toilets and diarrhea in the context of this study. The study findings showed hand washing did not vary while household water treatment and safe water storage declined respectively between 2010-2020. The observed increase in the use of clean toilets has had no effect on diarrhea between 2010-2020. This shows the complexity of the control of diarrhea among children under 5 years old. There is a need to (a) investigate area-specific factors to understand the inhibitors of the adoption of household WASH behaviors and (b) improve the design and the implementation of household WASH interventions for a significant reduction of diarrhea among children under 5 years old in Rwanda.

Introduction

A household constitutes a living, occupational and recreation place for children and contributes to the survival and healthy development of children through its social, environmental, and economic conditions. Various studies conducted at different times and places investigated household drinking water treatment, safe water storage, sanitation, and hygiene their relationship with diarrhea among children under 5 years old. These household behaviors/practices have been found to be potential household-level diarrhea risk factors in children under 5 years old (Darvesh et al., 2017; Pintu, 2020; Saha et al., 2022; Sahiledengle et al., 2021; Sinharoy et al., 2017). In terms of diarrhea prevention and control, household WASH is currently the main component of the interventions/ programs' (a) implementation, (b) monitoring, and (c) evaluation to prevent and reduce diarrhea among children under 5 years old. A combination of interventions to improve the access of clean water, sanitation, and hygiene facilities to households coupled with health education for behavior change showed diarrhea risk reductions between 27% and 53% in children under 5 years old (Darvesh et al., 2017). A study conducted by Nguyen et al. (2021) shows a 43% reduction in diarrhea in Sub-Saharan Africa was associated with home-based water treatment. A systematic review conducted by Wolf et al. (2022) revealed a reduction of up to 50% in diarrhea due to home-based water treatment. Sinharoy et al. (2017) in the cRCT conducted in Rusizi district of Rwanda did not find a relationship between the increase in home-based water treatment and diarrhea. In Rwamagana district of Rwanda, a RCT showed using filters for home-based water treatment reduced up to 49% of reported diarrhea among children

under 5 years old (Haque et al., 2022). At the time of this study, it was not known the characteristics of the association between household WASH behaviors and diarrhea varied in the context of Rwanda between 2010-2020. This study focused on the relationship between household water treatment, household safe water storage, household sanitation, and hand washing and diarrhea between 2010-2020 in Rwanda.

Literature Review

Recently, research results have identified from different places mainly in developing countries that household WASH conditions are risk factors for diarrhea. In an experimental study conducted in Zambia by Quick et al. (2002) on household water treatment and safe storage with a compliance of 97% chlorine use and 89.2% safe storage showed a diarrhea risk reduction of 48% for individuals in the intervention households compared to the control households. In the present study I assessed the relationship between household water treatment, safe water storage, sanitation, and hand washing and diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Household Water Treatment

In Rwanda, 80% of households have access to improved sources of drinking water including piped water, public taps, standpipes, tube wells, boreholes, protected dug wells, and bottled water in 2020. Except for bottled water, home-based quality improvement is best than source-based quality improvement due to poor handling practices that increase the risk of contamination of water during fetching, transport, and household storage before and/ or during its use (Clasen, 2015; NISR, 2020; Soboksa et al., 2020).

A study conducted by Nguyen et al. (2021) shows a 43% reduction in diarrhea in Sub-Saharan Africa was associated with home-based water treatment. A systematic review conducted by Wolf et al. (2022) revealed a reduction of up to 50% in diarrhea due to home-based water treatment. Sinharoy et al. (2017) in the cRCT conducted in Rusizi district of Rwanda did not find a relationship between the increase in home-based water treatment and diarrhea. In Rwamagana district of Rwanda, a RCT showed using filters for home-based water treatment reduced up to 49% of reported diarrhea among children under 5 years old (Haque et al., 2022). In Rwanda, water treatment options at the household level include mainly boiling, filtration, and chemical treatment (Sur'eau). The household's aptitude to access one of the water treatment options depends on the location and/or the purchasing power of the household.

For the purpose of this study, the variable [household water treatment] has values in the datasets [boiling, filtration, chemical treatment, any water treatment used to make water safe, no treatment]. The researcher then assessed the relationship between home-based water treatment with any option and diarrhea in the context of Rwanda between 2010-2020 and across communities.

Household Safe Water Storage

In 2005, a systematic review first identified the protective effect of household water treatment and storage interventions against diarrhea and their apparent advantage over interventions at the source or at other points of distribution, such as community wells and tap stands. The pooled estimate of the effect of home-based water treatment was a reduction in risk (RR = 33 %, 95 % CI[8–53 %]) or (RR = 45 %, 95 % CI[19–62

%) when combined with safe storage. The percentage of intervention households storing water safely increased from 41.5% to 89.2%. Stored water in intervention households was significantly less contaminated with Escherichia coli than water in control households ($P < 0.001$). Diarrheal disease risk for individuals in intervention households was 48% lower than for controls. In Rwanda, the relationship between household safe storage of water and diarrhea among children under 5 years old was not known at the time of the study. The present study assessed the relationship between household safe storage of water and diarrhea among children under 5 years old between 2000-2020 in Rwanda. The sub-set variables of safe storage of water include (a) water is stored with values Yes, No, (b) how water is stored with values jerry can, pot, bottle, cooking pot, and other, and (c) frequency of washing water containers with values less than 7 times or 7 times and plus as indicated in the RDHS dataset.

Household Sanitation

Since the decade of water and sanitation (1981-1990), household sanitation includes safe disposal of fecal matter, wastewater/liquid waste, and solid waste in general. In the context of this study, household sanitation is limited to disposal of human excreta. Indeed, human wastes (excreta) are the main source of pathogens causing diarrhea once ingested. The literature review conducted in 1991 revealed that household sanitation interventions reduced diarrhea by 36% on average while the most recent systematic found an overall diarrheal reduction of 25% attributable to household sanitation (Contreras & Eisenberg, 2019). In the context of current professional practice and demographic health surveys, safe household sanitation has three safe excreta disposal

behaviors including (a) using an improved latrine (adequate infrastructure and superstructure with adequate pit, floor, walls, and roof), (b) using a clean toilet (clean and dry platform without feces, urine, and flies), and (c) safe disposal of child feces as indicated in the RDHS dataset. Use of clean toilet (clean and dry platform without feces, urine, and flies) was used as a variable of household safe sanitation with values Yes, No.

Handwashing

Handwashing constitutes a cost-effective intervention that plays a key role in preventing diarrhea when practiced adequately. Precisely, handwashing with water and soap after defecating, after touching feces, before breastfeeding, before preparation of food, and before eating prevents between 25 and 53% of diarrhea among children under 5 years old (Nguyen et al., 2021; Solomon et al., 2021). This is the most impactful practice compared to other WASH practices and yet the least adopted in Rwanda (NISR, 2020). Indeed, addressing the handwashing issue can serve to limit the ingestion of pathogens and prevent the effect of poor sanitation as well as ensure safe feeding practices (Esrey et al., 1985). There was a need to assess the relationship between hand washing and diarrhea in Rwanda between 2010-2020. The sub-set variables include fixed place of washing hand with values observed, not observed and water at the place of washing hand with values available, not available.

Significance of the Study

The Demographic Health Surveys reports between 2010-2020 and findings of research studies conducted in Rwanda showed a stagnant and slow reduction of diarrhea among children under 5 years old with time. This research study assessed (a) household

level risk factors in terms of WAH behaviors, (b) their level of relationship with diarrhea, and (c) their variability with time and across communities. Indeed, it was intended that the research study results (a) contribute to a better understanding of household-level predictors in terms of WAH behaviors including household water treatment, household safe water storage, household sanitation, and hygiene and their variability with time across communities in Rwanda and (b) guide the design and the implementation of appropriate and community-specific household interventions to maximize the reduction of diarrhea among children under 5 years old in Rwanda. The identified and characterized associated household-level risk factors will inspire policy/program implementers to focus on high-risk factors and deploy more efforts and resources to high-risk areas across communities in Rwanda (Darvesh et al., 2017; Pintu, 2020; Saha et al., 2022; Sahiledengle et al., 2021; Sinharoy et al., 2017). The theoretical framework for this research consisted of the socio-ecological model which was used to connect the household level WASH behaviors (household water treatment, household safe water storage, household sanitation, and handwashing) and child health. Indeed, household level conditions vary across communities and over time and can unequally predict diarrhea among children under 5 years old. The interventions to address the identified household-level risk factors of diarrhea will be guided by the present research results to improve and strengthen household's adoption sustainability of safe behaviors for maximum reduction of diarrhea and better child health (Ahsan et al., 2017; Alemu et al., 2017; Glanz & Bishop, 2010; National Academies of Sciences, Engineering, and Medicine, 2001; Pinzón-Rondón et al., 2015). The original contribution of this research

study resides in the description of the household-level risk factors in terms of WASH behaviors for diarrhea, their prevalence, their level of relationship with diarrhea among children under 5 years old, and their variability with time and across communities in Rwanda. The study results constitute a basis for researchers and policy implementers for (a) further research on area-specific motivators and inhibitors of household WASH adoption sustainability and (b) the design/adaptation of existing interventions and implementation of area-specific interventions to maximize the reduction of diarrhea in Rwanda respectively. The research results consist of a tool for communities (health centers, sectors, cells, and villages) to be more focused in the improved implementation and the monitoring of diarrhea related interventions for maximum outcomes.

Purpose of the Study, Research Questions, and Hypotheses

The purpose of the present research study was to assess the relationship between household WASH behaviors (home-based water treatment, safe water storage, handwashing, use of clean latrine) and diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Research question: Is there any relationship between household WASH behaviors (household water treatment, household safe water storage, household sanitation, and hand washing) and diarrhea among children under 5 years old between 2010-2020 in Rwanda?

H_0: There is no relationship between household WASH behaviors (household water treatment, household safe water storage, household sanitation, and hand washing) and diarrhea among children under 5 years old between 2010-2020 in Rwanda.

H_1: There is a relationship between household WASH behaviors (household water treatment, household safe water storage, household sanitation, and hand washing) and diarrhea among children under 5 years old between 2010-2020 in Rwanda.

Methods

Data Collection and the Study Participants

The study used secondary data from the National Institute of Statistics of Rwanda and the study participants are households with 12,538 households for 2010 survey, 12,699 for 2015 survey, and 13,949 households for 2020 survey as sample size after data cleaning.

Variables

The independent variables include household water treatment, household safe water storage, household sanitation, and hand washing (all categorical). The variable household water treatment has had its values adjusted to [any water treatment used to make water safe, no treatment]. The variable safe storage of water was assessed through frequency of washing water containers with values [less than 7 times, 7 times and plus] as indicated in the RDHS dataset. The variable household sanitation was assessed through use of latrine with clean and dry platform with values [Yes, No]. Regarding hand washing, the sub-set variable consisted of fixed place of washing hand with values [observed, not observed]. The dependent variable was the prevalence of diarrhea among children under 5 years old. The study used secondary data from Rwanda Demographic Health Surveys of 2005, 2010, 2015 and 2020 retrieved from the Rwanda National Institute of Statistics website.

Design and Analysis

The study consisted of a cross-sectional study design and used descriptive statistics, pairwise comparisons, and linear regression designs to assess (a) the prevalence of WASH behaviors across communities, regions, and urban-rural areas in 2010, 2015, and 2020, (b) the variation of WASH behaviors over time, and (c) if household WASH behaviors (household water treatment, household safe water storage, household sanitation, and hand washing) are predictors of diarrhea among children under 5 years old in Rwanda. The pairwise comparisons and linear regression designs were used with continuous variables.

Results

The results reveal the prevalence of household WASH behaviors, the variation of household WASH behaviors, and the relationship between household WASH behaviors and diarrhea between 2010-2020.

Descriptive Analysis

Descriptive analysis was used to calculate the prevalence of households with handwashing, water treatment, safe water storage, and use of clean latrine districts/communities, regions, and urban-rural areas in 2010, 2015, and 2020 (Table 1).

Table 1

Prevalence of Household WASH Behaviors Between 2010-2020

	2010				2015				2020			
Community (District)	Handwashing facility	Water treatment	Safe water storage	Clean latrine	Handwashing facility	Water treatment	Safe water storage	Clean latrine	Handwashing facility	Water treatment	Safe water storage	Clean latrine
Nyarugenge	15.4	63.7	12.7	61.7	7.1	68.3	4.6	54.7	14.2	55.4	2.2	65.7
Gasabo	8.2	71.1	14.2	44.7	15.6	60.1	5.8	55.5	11.5	46.3	3.6	66.8
Kicukiro	11.0	80.1	16.8	69.5	32.0	72.6	6.4	79.6	28.1	53.3	3.7	72.7
Nyanza	10.6	45.9	5.4	40.5	1.7	37.0	2.0	59.1	18.2	39.7	1.8	45.3
Gisagara	35.1	27.4	4.5	39.3	2.2	25.4	9.0	21.0	7.0	16.1	6.2	43.4
Nyarubuye	5.4	36.0	8.7	32.9	30.8	31.1	3.2	50.4	6.6	27.0	2.9	54.8
Huye	6.3	59.2	14.9	31.0	41.8	51.4	4.1	54.8	13.3	26.0	7.9	54.4
Nyamagabe	9.0	43.3	18.6	38.4	11.8	50.7	5.8	52.4	5.0	21.3	2.4	53.2
Ruhango	2.0	43.4	0.9	35.0	13.5	29.8	1.9	45.2	12.2	44.8	1.1	44.3
Muhanga	9.8	79.3	19.2	43.5	14.4	66.6	3.9	42.2	10.6	46.2	0.5	53.8
Kamonyi	1.5	67.2	5.5	39.5	5.0	47.6	4.3	37.6	10.1	46.6	3.1	59.6
Karongi	2.5	41.4	3.4	46.7	1.2	57.3	5.8	38.5	10.5	46.0	3.3	47.0
Rutsiro	6.5	31.7	4.6	33.4	4.1	51.2	3.7	33.7	6.7	17.5	4.3	32.7
Rubavu	0.7	36.9	7.9	31.6	30.1	35.4	4.3	39.5	4.8	41.4	1.8	51.6
Nyabihu	6.7	62.1	8.7	27.3	35.2	24.0	0.0	30.8	3.8	48.8	2.6	34.1
Ngororero	1.7	59.3	5.0	37.7	3.6	47.1	1.8	22.9	4.1	43.8	2.4	45.7
Rusizi	3.9	34.4	7.6	34.5	5.0	49.5	3.8	49.2	7.1	27.3	5.5	63.5
Nyamashek e	8.5	52.4	5.7	48.1	19.1	45.7	6.9	47.2	11.1	34.1	5.9	56.9
Rurindo	6.6	28.7	7.8	33.7	9.9	44.6	1.7	38.6	5.3	48.4	4.2	46.2
Gakenke	11.8	62.9	10.3	23.1	5.6	67.5	3.1	39.8	32.5	46.3	2.7	66.3
Musanze	5.6	57.1	5.7	38.8	5.6	62.2	2.1	34.9	12.0	40.7	6.3	51.4
Burera	19.5	48.1	7.2	36.0	1.5	31.5	2.0	31.2	3.2	21.4	3.6	45.6
Gicumbi	3.7	40.1	10.9	33.9	13.8	39.9	1.6	58.4	5.3	27.3	0.0	36.7
Rwamagana	6.9	52.0	3.3	53.4	9.2	34.4	4.7	54.7	13.8	29.1	2.6	62.5
Nyagatare	7.1	52.5	2.1	42.2	4.6	40.7	1.9	61.7	13.6	37.1	1.9	58.4
Gatsibo	38.7	35.1	2.5	45.1	3.4	29.6	20.8	35.4	10.1	26.6	0.0	49.3
Kayonza	31.6	60.8	6.1	49.0	33.9	50.5	0.9	52.9	13.4	33.3	8.3	50.7
Kirehe	14.9	52.8	6.5	42.8	2.4	49.2	1.8	49.2	21.6	31.2	2.1	58.1
Ngoma	19.0	34.5	3.6	31.6	4.3	33.3	1.9	51.9	14.9	39.4	1.3	65.1
Bugesera	2.4	26.7	1.2	45.0	4.4	37.9	0.0	47.3	7.5	26.8	4.4	40.0
Region												
Kigali City	11.5	71.6	14.6	58.7	18.2	67.1	5.6	63.3	17.8	51.6	3.1	68.4
Southern	10.0	50.1	9.2	37.5	15.1	42.5	4.1	45.3	10.5	33.7	2.7	51.0
Western	4.3	45.4	5.9	37.0	14.0	44.3	4.0	37.4	6.9	37.0	3.4	47.3
Northern	9.4	47.4	8.2	33.1	7.3	49.1	2.2	40.6	11.7	36.8	3.6	49.3
Eastern	17.3	44.9	3.7	44.2	8.9	39.4	4.0	50.4	13.6	31.9	2.9	54.8

	2010				2015				2020			
Community (District)	Handwashing facility	Water treatment	Safe water storage	Clean latrine	Handwashing facility	Water treatment	Safe water storage	Clean latrine	Handwashing facility	Water treatment	Safe water storage	Clean latrine
Urban/rural												
Urban	13.3	66.2	14.2	56.7	20.0	67.3	5.4	61.9	19.1	54.2	3.5	66.8
Rural	9.9	46.9	6.3	37.8	10.4	40.0	3.4	41.5	9.3	31.7	2.9	48.9
Total average	10.5	50.0	8.1	40.8	12.6	46.2	4.0	46.1	11.5	36.7	3.1	52.9
Total sample	12, 538				12, 699				12, 949			

Pairwise Comparisons

The results of the repeated measures analysis show in Table 3 a decrease in water treatment (μ = 13.230, 95%CI [8.609; 17.851], p <.001) and safe water storage (μ = 4.430, 95%CI [2.400; 6.460], p <.001) between 2010 and 2020. For the same period, safe sanitation increased (μ = 12.197, 95%CI [8.158; 16.235], p <.001). The pairwise comparison shows the effect size of (F = 17.471, p <.001) for water treatment, (F = 11.343, p <.001) for safe water storage, and (F = 18.258, p <.001) for safe sanitation based on Greenhouse-Geisser test within subjects.

Table 2

Effect of Time on Household WASH Behaviors Between 2010-2020

	Hand washing		Water treatment		Safe water storage		Safe sanitation	
Factor	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Time	.317	.694	17.471	<.001	11.343	<.001	18.258	<.001

Table 3

Variation of Household WASH Behaviors in Time Between 2010-2020

(I) Handwashing facility	(J) Handwashing facility	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-2.007	2.956	.503	-8.052	4.038
	3	-.850	2.021	.677	-4.984	3.284
2	1	2.007	2.956	.503	-4.038	8.052
	3	1.157	2.521	.650	-4.000	6.313
3	1	.850	2.021	.677	-3.284	4.984
	2	-1.157	2.521	.650	-6.313	4.000
(I) Water Treatment	(J) Water Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	3.800	2.281	.107	-.866	8.466
	3	13.230*	2.260	<.001	8.609	17.851
2	1	-3.800	2.281	.107	-8.466	.866
	3	9.430*	2.372	<.001	4.579	14.281
3	1	-13.230*	2.260	<.001	-17.851	-8.609
	2	-9.430*	2.372	<.001	-14.281	-4.579
(I) Safe Water Storage	(J) Safe Water Storage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	3.723*	1.142	.003	1.388	6.059
	3	4.430*	.992	<.001	2.400	6.460
2	1	-3.723*	1.142	.003	-6.059	-1.388
	3	.707	.841	.408	-1.013	2.426
3	1	-4.430*	.992	<.001	-6.460	-2.400
	2	-.707	.841	.408	-2.426	1.013
(I) safe sanitation	(J) safe sanitation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-5.347*	2.073	.015	-9.586	-1.107
	3	-12.197*	1.975	<.001	-16.235	-8.158
2	1	5.347*	2.073	.015	1.107	9.586
	3	-6.850*	2.022	.002	-10.985	-2.715
3	1	12.197*	1.975	<.001	8.158	16.235
	2	6.850*	2.022	.002	2.715	10.985

*. The mean difference is significant at the .05 level

Linear Regression

Using the linear regression analysis, the linear regression model was not statistically significant (Table 4). None of the independent variables predict diarrhea in the context of this study between 2010-2020.

Table 4

Relationship Between Diarrhea and Household WASH Behaviors Between 2010-2020

Health Outcome: Diarrhea 2010				
Predictors	B	Sig.	95.0% Confidence Interval for B	
			Lower Bound	Upper Bound
Hand Washing Facility 2010	.082	.380	-.106	.270
Water Treatment 2010	-.083	.274	-.235	.069
Safe Water Storage 2010	.338	.113	-.085	.761
Safe sanitation 2010	-.132	.192	-.336	.071
Health Outcome: Diarrhea 2015				
Predictors	B	Sig.	95.0% Confidence Interval for B	
			Lower Bound	Upper Bound
Hand Washing Facility 2015	-.028	.765	-.219	.163
Water Treatment 2015	.035	.671	-.134	.204
Safe Water Storage 2015	.275	.329	-.294	.845
Safe sanitation 2015	-.112	.245	-.307	.082
Health Outcome: Diarrhea 2020				
Predictors	B	Sig.	95.0% Confidence Interval for B	
			Lower Bound	Upper Bound
Hand Washing Facility 2020	-.089	.616	-.451	.273
Water Treatment 2020	.164	.100	-.034	.362
Safe Water Storage 2020	.215	.642	-.724	1.154
Safe sanitation 2020	-.189	.122	-.432	.054

Discussion

Interpretation

Using the multiple regression analysis, the multiple regression model was not statistically significant, and this confirms our hypothesis that there is no relationship between household WASH behaviors and diarrhea in 2020, 2015, and 2020 (Table 4). Hand washing, which is the most cost-effective behavior to prevent the ingestion of pathogens and diarrhea did not change between 2010-2020 (Table 3) and this can contribute to the stagnant prevalence of diarrhea in the country (Esrey et al., 1985; Nguyen et al., 2021; Solomon et al., 2021). The increase in safe sanitation (12.197%) (Table 3) had no effect on diarrhea between 2010-2020 (Table 4). The model showed a relatively small size effect ($F = 18.258$, $p < .001$) in the case of safe sanitation (Table 2). The positive changes in sanitation observed were relatively small to trigger a significant reduction of diarrhea in the context of this study which can explain the absence of relationships between sanitation behavior and diarrhea among children under 5 years old. The findings of this study are consistent with the study of Sinharoy et al. (2017) conducted in Rusizi district of Rwanda which did not find any effect on diarrhea despite improvements in home-based water treatment (20%) and sanitation (14%) between 2013 and 2015. A similar study conducted in Nepal shows an increase in household safe sanitation (22%) coupled with an increase in safe water (40%) and handwashing (up to 35.3 %) reduced diarrhea by 12%-85% (Meierhofer et al., 2023). Higher adoption of and consistent WASH behaviors including handwashing, drinking water treatment, safe water storage, and safe sanitation are required to reduce the risks of diarrhea (Darvesh et al.,

2027; Haque et al., 2022; Nguyen et al., 2012; Wolf et al., 2022). Local underlying factors including motivators and inhibitors of adoption of WASH interventions and consistent household WASH behaviors must be considered in the context of the socioecological model for improved control of diarrhea through adapted policy and effective implementation of WASH interventions. Consistent implementation, high coverage, and adoption sustainability of WASH behaviors are mandatory for significant and sustained reduction of diarrhea (Chirgwin et al., 2021; Martin et al., 2018).

Limitations

The study was limited to secondary data analysis and interpretation. The variables used in the study were defined in the context of Rwanda Demographic Health Surveys. I relied on the information provided by the survey respondents irrespective of their intent other than the survey purpose.

Implications

The findings of this study constitute an eye-opener and give insights into improving the assessment of WASH-related diarrhea risk factors, designing, and implementing area-specific control interventions for maximum (a) household WASH behavior change and (b) reduction of diarrhea among children under 5 years old across communities in Rwanda (Ahsan et al., 2017; Cavalcanti et al., 2019).

Recommendation

Further research activities are needed to assess the feasibility of local-contextual WASH-related diarrhea control interventions and their adoption sustainability to

maximize the reduction of diarrhea among children under 5 years old in Rwanda (Glanz & Bishop, 2010; Mansnerus, 2014; Okoyo et al., 2021).

Conclusion

The study results did not find a significant relationship between hand washing, water treatment, safe water storage, and use of clean toilets and diarrhea in the context the study, despite their documented proven strong influence on diarrhea among children under 5 years old between 2010-2020. Indeed, the study findings show hand washing did not vary while household water treatment and safe water storage declined respectively between 2010-2020. The increase in the use of clean toilets has had no effect on diarrhea between 2010-2020. This shows the complexity of the control of diarrhea among children under 5 years old. There is a need to (a) investigate area-specific diarrhea risk factors to understand the inhibitors of the adoption of the household WASH behaviors and (b) apply strategies to maximize household WASH behavior change and adoption sustainability to significantly reduce diarrhea among children under 5 years old in Rwanda.

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Part 3: Summary

Integrated Study Findings

Within the general objective of understanding the spatial-temporal variation of diarrhea and associated sociobehavioral factors in Rwanda between 2010-2020, I conducted three integrated studies. The findings of the first study did not show any significant variation of diarrhea among children under 5 years old over time between 2010-2020 but highlighted a variation of diarrhea across districts/communities, regions, and urban-rural areas of Rwanda in 2010, 2015, and 2020. Some districts of the Western, Southern, and Northern regions were consistently at higher risk of diarrhea, and the difference between urban-rural areas increased with time between 2010-2020. The findings of the first study suspect diverse and uneven distribution of risk factors for diarrhea but also question the quality of the design and the implementation of existing diarrhea control interventions and suggest more research to understand the area-specific key diarrhea risk factors for area-specific design and implementation of diarrhea control interventions to ensure significant reduction of diarrhea in Rwanda. The second study assessed the influence of mothers' highest education level attained, employment status, and acknowledgement of domestic violence on diarrhea among children under 5 years old. The findings of the second study confirmed the lower education level attained by the mother, the higher likelihood of diarrhea among children under 5 years old while not having a decision on own health care and acknowledgment of domestic violence by the mother increase the likelihood of diarrhea among children under 5 years old in Rwanda. The third study assessed the relationship between diarrhea and household WASH

behaviors. The findings of this study did not find any significant relationship between diarrhea and household WASH behaviors between 2010-2020. Even though the use of clean latrines increased by 12.7% between 2010-2020 on one side, hand washing did not vary while water treatment and safe water storage significantly declined continuously between 2010-2020 on the other side. All three studies investigated diarrhea risk factors of diarrhea among children under 5 years old. The findings of the three studies showed the multilevel aspect of diarrhea risk factors and the complexity of the control of diarrhea and call for the use of the socioecological model to understand and address the issue of persisting diarrhea among children under 5 years old through quality design and effective implementation of area-specific control interventions for a significant reduction of diarrhea (Cavalcanti et al., 2019; Durlak & DuPre, 2008; Glanz & Bishop, 2010; Golden & Earp, 2012).

Potential Social Change and Areas of Future Research

The overall study findings constitute a basis of assessing and understanding area-specific diarrhea risk factors to adapt and improve the design and the implementation of diarrhea control interventions to ensure a significant reduction of diarrhea among children under 5 years old in Rwanda. Two areas of future research include (a) assessing and understanding of area-specific risk factors for diarrhea among children under 5 years old in Rwanda and (b) conceptualizing an integrated mathematical and dynamical model to promote the design and the implementation of area-specific diarrheal disease control interventions in Rwanda for maximum coverage, adoption and health effect.

Conclusion

Diarrhea risk factors are multilevel (community, household, individual) and unevenly distributed across community/districts, regions, and urban-rural areas. Based on the existing (a) stagnant reduction of diarrhea among children under 5 years old, (b) diarrhea high-risk areas, and (c) lack of effect of existing control interventions on diarrhea, there is a need to assess and understand area-specific diarrhea risk factors. The quality design and effective implementation of area-specific diarrhea control interventions with consideration of coverage and adoption sustainability are urgent for a significant reduction of diarrhea among children under 5 years old in Rwanda.

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