2017

The Effects of Improved Water and Sanitation Access on Under Five Child Diarrhea in Peru

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The Effects of Improved Water and Sanitation Access on Under Five Child Diarrhea in Peru

CAPSTONE PROJECT PAPER

A paper submitted in partial fulfillment of the requirements for the degree of
Masters of Public Health
in the
University of Kentucky College of Public Health

By
April Ballard
Lexington, Kentucky
April 20th, 2017

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Abstract

Significance: Diseases related to poor or lack of access to clean water, sanitation, and hygiene negatively impact health, education, and development worldwide and cause millions of deaths in children each year. Health outcomes associated with lack of access to clean water and sanitation are under-evaluated.

Aim: To assess the effect of improved water and sanitation infrastructure development on child morbidity in Peru by investigating diarrhea in children under five years of age.

Methods: The child, family, and household data from the Peruvian Demographic and Health Surveys (DHS) were used to evaluate the association between access to water and sanitation and diarrhea in children under five using logistic regression analysis.

Results: This study found an association between under five years of age diarrhea and improved sanitation access, current age of child, and the interaction between drinking water access and natural region. Safe disposal of child's stool appeared to be protective against diarrhea, but was not statistically significant (OR=0.87, p=0.0642). Improved sanitation was protective (OR=0.85), being younger increased risk of diarrhea with those 6-11 and 12-23 months with highest odds (OR=2.56; OR=3.47), and those living in the Rainforest with improved and unimproved water access had increased risk of diarrhea (OR=1.78; OR=2.62).

Conclusion: Natural region is the primary factor predicting diarrhea risk, as well as type of drinking water, specifically for those living in the rainforest natural region. The rainforest region of Peru has the highest rates of diarrhea and the highest proportion of poor people. As with many diseases, further research of Peruvian regions and states suggest that multifactorial causes of diarrheal diseases could be at play.

Introduction

Efforts to improve access to water, sanitation, and hygiene (WASH) have been developing globally for decades. Specifically, the United Nations developed the Millennium Development Goals (MDGs), which included a goal of halving the proportion of people worldwide without sustainable access to safe drinking water and basic sanitation by 2015. As of 2015, the global MDG for drinking water was met, while the sanitation MDG was missed by almost 700 million people [1]. While significant progress has been made in WASH development in regards to access, many populations have yet to meet these goals. Additionally, data regarding the true effects of WASH accomplishments are limited. Health indicators, beyond simply access to improved WASH, must be analyzed in order to determine if improved access is resulting in reduced death and disease [2,3].

Diseases related to poor or lack of access to water, sanitation, and hygiene cause millions of deaths in children and negatively impact health, education, and development worldwide [4]. The global under-five mortality rate has decreased from 91 to 43 deaths per 1,000 live births from 1990 to 2015, a reduction of over 50%. Despite the tremendous strides made towards reduction of child mortality, in 2015 there were still 5.9 million deaths in children under the age of five, which is 16,000 deaths per day [5]. Although these deaths result from a variety of conditions, 1.5 million child deaths are related to ingestion of unsafe water, lack of sanitation access, and lack of water for hygiene. Data show that 88% of deaths associated with diarrhea can be ascribed to unsafe water, insufficient sanitation, and inadequate hygiene [6].

While nations in sub-Saharan Africa and Oceania have the greatest need for improved access to drinking water and sanitation, other regions of the world, especially those with greater proportions of rural populations, still have great need [7]. In particular, Latin America has a great need for investment in water infrastructure due to gross inequalities in wealth and development throughout the region [3,7]. Peru is among the top 15 countries in the world with the most freshwater per capita, however the country still suffers from water scarcity [8,9]. Water and sanitation distribution, both rural and urban, varies in amount and quality throughout the country, making Peru have the greatest inequalities related to water in Latin America [10]. It is estimated that eight million people lack adequate sanitation facilities and four million people lack access to clean water [9,10]. With a total population of roughly 31 million, that means that 26% of Peruvians still lack developed sanitation and 13% adequate water. In rural areas, disparities are greater with 31% and 43% lacking adequate facilities respectively [11,12].

Mirroring the global infrastructure agenda with the guidance of the MDGs, Peru has set out to extend WASH infrastructure in recent decades through various projects and investments. The development of the *Agua Para Todos* program in 2006 was the beginning of the Peruvian governments attempt to increase access to safe water and sanitation for the nation's poor [13]. Specifically, this program seeks to provide high quality services, both water and sanitation, through investment in community members, local and national government, and the private sector [13, 14].

While development efforts continue in the country, limited research has been performed beyond documenting the percentage of Peruvians with WASH access. Although increasing access to water and sanitation is essential for the welfare and development of the country, the health impacts of access are equally important. As programs seeking to improve Peruvian water and sanitation continue to be implemented, evaluation of progress using both infrastructure and health indicators is lacking. These measures are important and necessary for assessment, as well as future programmatic development planning.

This paper therefore aims to evaluate the effects of improved water and sanitation infrastructure on child health in Peru. Specifically, this article seeks to investigate the impact of improved water and sanitation on child morbidity due to diarrhea in children under five.

Methodology

Study Design and Data

The child, family, and household data from the Peruvian Demographic and Health Surveys (DHS) were used to perform a cross-sectional study assessing the impact of access to improved water and sanitation on child morbidity. Specifically, the occurrence of diarrhea in the past two weeks in children under five was used as a primary outcome measure. While diarrhea in the past two weeks serves as a short-term health indicator, repeat or severe diarrhea can lead to medium- to long-term health impacts. Thus, this outcome measure served as a proxy for longer health impacts.

National data collection from Peru is continuous in five yearly phases, providing data for a wide range of indications led by the United States Agency for International Development (USAID) [15]. While data is collected every year in Peru, the latest data available for download and analysis are from 2012. Households are selected based on stratified two-stage cluster design sampling. The first stage selects Enumeration Areas (EA) using Census files. The second stage selects a sample of households drawn from an updated list of households within each EA selected in stage one. A variety of survey tools are used with DHS, including questionnaires, biomarkers, and geographic information [15]. IRB approval was not necessary due to lack of any type of identifying information related to data.

Variable Selection

DHS provides data at the household level, as well as a variables specific to individuals in the household. Since the primary propose of this paper was to assess water and sanitation access, as well as find determinants of diarrhea in children under five, variables of interest focused on child, familial, and household characteristics. The DHS surveys record women's responses regarding birth history. As surveys are conducted within households, information and measurements regarding each child's health is collected, as well as household access to water and sanitation, information about the family, and a large number of potential household and demographic confounders [15].

Demographic and economic variables included type of residence, natural region, wealth index, number of household members, mother's and father's education level, and mother's and father's age. Wealth index was collapsed from 5 to 3 categories by combining poorest and poorer and richer and richest.

Child variables included whether the child had diarrhea in the past 2 weeks, current age in months, sex, and disposal method of stool. A child's stool disposal variable was created by categorizing sanitation methods as safe or unsafe. Stool disposal was considered safe when minimal risk of fecal-oral transmission was possible. Methods deemed safe included when stool was rinsed into an improved toilet or latrine. Unsafe methods were when stool was left in the open, disposed of outside the dwelling, buried, rinsed in anything other than an improved toilet or latrine. Use of disposable diapers was also considered unsafe since solid waste disposal management is inadequate in Peru [16, 17].

Water and sanitation variables included if water was treated before drinking, type of toilet facility, and type of drinking water. Following WHO/UNICEF Joint Monitoring Program guidelines, a new variable for water sources was created by categorizing sources into improved and unimproved sources. Improved sources included piped water, public tap, standpipes, tube wells, protected dug wells, protected springs, and rainwater. Unimproved sources included unprotected springs, unprotected dug wells, tanker-truck, surface water, and bottled water. A new variable for sanitation was also made by categorizing sources as improved or unimproved following the WHO/UNICEF guidelines. Flush toilets, piped sewer systems, septic tanks, pit latrines with slab, ventilated pit latrines were considered as improved sources. Flush/pour to elsewhere, pit latrines without slab, bucket, shared sanitation, and no facilities or field disposal were considered unimproved sources [11]. No variable of interest had greater than a 15% missing rate.

Statistical Analysis

Initial exploratory analyses were performed using descriptive statistics with variables by children who had diarrhea in the past two weeks and those who did not. Table 1a-c present the study population demographics related to children under five years of age, including geographic, household, and familial characteristics. Descriptive analysis of Peruvian states was performed to help inform conclusions involving analysis with the four natural regions (Table 2). With 25 Peruvian states total, it is difficult to have enough statistical power for analysis and only investigating natural regions could be misleading. Thus, investigation of Peruvian states and child diarrhea was performed using descriptive data and natural region was used for logistic modeling. Additionally, analysis of under five diarrhea rates by sanitation and water access stratified by natural region was performed (Table 3a-d). Image 1 is a map of Peru depicting the coastal, sierra, and rainforest natural regions, as well as all 25 states. Univariate, bivariate, and multivariate logistic regression analyses were conducted using SAS software, version 9.4 (SAS Institute; Cary, NC, USA).

Bivariate logistic regression modeling was carried out to determine unadjusted associations between variables and child diarrhea status. Results from unadjusted analyses can be found in Table 4. Multiple logistic regression was used for the final model, with whether or not a child had diarrhea in the past 2 weeks as the outcome of interest. Statistical significance from bivariate analyses and previous studies were used to guide multivariable regression model variable selection. Forward stepwise selection with a significance level of five percent was carried out for this model using Akaike information criterion (AIC), starting with the main variables of interest, access to water and access to sanitation. Interactions were also tested for, which showed that wealth index and natural region were influencing access to water and the outcome of interest. Further investigation suggested that wealth index and natural region were correlated, measuring the same socioeconomic factors. Thus, only interaction between access to water and natural region was evaluated further and subsequently included in the final model (Table 5). Results for the final multiple logistic regression model can be found in Table 6.

Results

Data collected from women regarding all children under age five who were alive, resulted in a sample size of 9,449, of which 1,254 (13.3%) had diarrhea in the past two weeks; only 41 (0.04%) responses were missing diarrhea status. Table 1a-c present demographics related to children under 5 years of age. Of all participants, 5,328 (56.4%) of the total study population are poor. Almost all mothers have some education (95.9%), with the largest proportion of mothers having a secondary education level. Father's education level is similar with 92.5% having some education. The average household size in both those with diarrhea and without is roughly 5 persons. The current age of children is approximately distributed evenly among groups, however there are fewer children in the <6 months and 6-11 month categories. There are approximately the same number of male and female children. More participants live in urban area (57.8%) than rural and participants' distribution in natural regions varies with Lima Metro having the fewest number of participants (7.3%) and the Sierra having the most (38.5%). The Rainforest and Coast account for the rest of the population with 28.5% and 25.3% respectively. Specific to treatment of water before drinking it, a majority of participants do treat their water (80.8%). Furthermore, 78.8% have improved sources of drink water and 70.6% have improved toilet facilities.

Table 2 presents descriptive statistics for Peruvian states. The northern most Amazonian rainforest region, Loreto, has the most number of cases (184) and the highest rate of childhood diarrhea at 30.1%. Half of the population has unimproved sanitation and about half have unimproved water (48.1%). Of those with unimproved sanitation, most have no service or use a river or canal. The Amazonas region also has an above average rate of childhood diarrhea (19.9%) and is in the northern Amazon rainforest with some sierra areas. The level of unimproved sanitation and water are less dramatic compared to Loreto with 23% with unimproved sanitation and 16% unimproved water. However, many of those who have unimproved water, drink from the river or canal and this region has one of the highest poverty rates in the country (47.3%).

San Martín is another Amazonian region in the north with a diarrhea rate of 20.0%. In the region, 22% of people have unimproved sanitation and 21% unimproved water. Junin is another region with above average diarrhea rates compared to other regions (20.0%), but is in central Peru; this region is both considered to be both part of the sierra and the rainforest. Roughly 27% of people do not have access to improved sanitation, although almost everyone (98% of people) has access to improved water. Pasco is just north of Junin and has a diarrhea rate of 22.1%. Many people in this region have no sanitation service or use the river sanitation (48.8%). However, only 8% have unimproved sources of drinking water. Ucayali and Apurímac also have slightly elevated diarrhea rates (15.0% and 14.2% respectively) above the national rate of 13.3%. Ucayali is an Amazonian region with a quarter of people having unimproved sanitation and 35.1% having unimproved water. Apurímac is a sierra region with 30.2% having unimproved sanitation, but only 4.1% having unimproved drinking water. However, 42.8% of people in the region are impoverished. Image 1 is a map of Peru for geographical reference.

Tables 3a-d present under five diarrhea rate by types of water and sanitation access stratified by natural region. In the Lima Metropolitan region, differences in diarrhea rates based on types of water and sanitation access are not large, unless households have access to both improved sanitation and water (Table 3a). Those with unimproved sanitation and unimproved water access have the highest rate (16.7%). Those with unimproved sanitation and improved water, as well as those with improved sanitation and unimproved water have roughly the same rate of diarrhea (15.7% and 15.0% respectively). While those with improved sanitation and water access have the lowest rate (10.4%). In the Coastal natural region (Table 3b), those with unimproved sanitation and improved water access have the highest diarrhea rate (10.0%), and children with improved sanitation and improved water have roughly the same rate (9.4%). However, those with unimproved sanitation and unimproved water, as well as those with improved sanitation and unimproved water have lower rates of diarrhea (8.3% and 4.9% respectively). In the Sierra natural region those with unimproved sanitation and unimproved water have a diarrhea rate of 24.1%, while the other categories are quite different. 12.6% of children with unimproved sanitation and improved water in this region have diarrhea, 4.6% of children with improved sanitation and unimproved water have diarrhea, and 10.7% of children with improved sanitation and improved water have diarrhea (Table 3c). Table 3d presents the rates of diarrhea in children under five in the Rainforest natural region. Those with unimproved sanitation and unimproved water have a rate of 31.5%. Those with improved water and unimproved sanitation had roughly the same diarrhea rate as individuals with access to improved water and improved sanitation (17.5% and 17.9% respectively). Children with improved sanitation and unimproved water had a rate of 21.0%.

Table 4 presents bivariate analyses used for the development of the final logistic regression model. All variables are analyzed with whether the child had diarrhea in the past 2 weeks. In those that had diarrhea, having improved sanitation access and improved water access were protective compared to unimproved sources (OR=0.75 p<0.0001; OR=0.60 p<0.0001). Treating water before consuming was also protective against diarrhea compared to no treatment (OR=0.81 p=0.0053). Living in Lima metro, the Coast, and the Sierra was also protective against diarrhea compared to living in the Rainforest (OR=0.52 p<0.0001; OR=0.41 p<0.0001; OR=0.52 p<0.0001). Those who were rich were less likely to have diarrhea compared to those who were poor (OR=0.61 p<0.0001), but there was no significant difference in odds of diarrhea between those who were poor and those who were in the middle wealth index (p=0.34). Younger children were more likely to have diarrhea compared to those who were 48-59 months old, with those 6-11 months old and 12-23 months old having the greatest odds of diarrhea (OR=3.02 p<0.0001; OR=3.80 p<0.0001). Safe disposal of the child's stool compared to unsafe disposal was protective against diarrhea (OR=0.68 p<0.0001), as well as mothers who were older compared to those less than 20 years old. A larger number of household members was found to increase the risk of diarrhea slightly (OR=1.04 p=0.0016). Type of residence, sex of child, mother's education, father's age, and father's education were found to be insignificant.

Table 5 presents information regarding the interaction between natural region and type of drinking water access on diarrhea. The effects of water access on diarrhea differ by natural region. Living in the Rainforest region increased risk of diarrhea for both unimproved and improved water sources (OR=2.67 p<0.0001; OR=1.72<0.001) compared to those living in Lima metro with improved sources of water. Living in the Coast region with unimproved water sources was protective against diarrhea (0.48 p<0.05) compared to Lima with improved water sources. All other categories were not statistically significant.

Table 6 evaluates the adjusted associations between select variables and diarrhea in children under five. Improved sanitation access was found to be protective against diarrhea compared to no treatment (OR=0.85 p=0.0027). Safe disposal of child's stool compared to unsafe disposal also appears protective against diarrhea (OR=0.87 p=0.0642). Current age of child was found to be significantly associated with diarrhea. Younger children were more likely to have diarrhea compared to those who were 48-59 months of age. Those who were 6-11 months old and 12-23 months old had the greatest odds of diarrhea (OR=2.56 p<0.0001; OR=3.47 p<0.0001), but all ages had statistically significant increased odds compared to those age 48-59 months. Type of drinking water access and natural region were analyzed as an interaction variable. Similar to the findings in Table 5, those living in the Rainforest with unimproved and improved water sources had increased risk of diarrhea (OR=1.78 p<0.0001; OR=2.62 p<0.0001) compared to those living in Lima metro with improved water. Those living in the Coastal region with unimproved water were protected against diarrhea (OR=0.48

p=0.0257), while all other categories were statistically insignificant. The Hosmer and Lemeshow Goodness-of-Fit test showed this model to be appropriate (p=0.1933).

Discussion

Due to lack of research on the health effects of water and sanitation infrastructure in Peru, this study evaluated the impact of improved water and sanitation on child morbidity, specifically investigating diarrhea in the past two weeks. Children under five with access to improved drinking water, improved sanitation, and living in any natural region other than the rainforest were found to have lower risk of diarrhea. Older children (greater than 48 months) had the lowest risk of diarrhea compared to younger children. Safe disposal of children's stool was also protective. It is important to clarify that the effects of water access on diarrhea differed by natural region. While unimproved water sources were related to increased risk of diarrhea in all the regions, only strong, statistically significant differences were seen in the Rainforest region.

Specific to child age, other studies have found similar patterns with diarrhea and age of child in months, with peaks at 6-11 months and 12-23 months [18,19].. This is thought to be due to host characteristics such as vulnerability of the most immature immune system, with older ages developing immunity to certain pathogens and those less than 6 months having less mobility and exposure to pathogens compared to those between 6 and 23 months [18,19]. Also, children under 6 months may retain passive immunity provided from the mother.

While the DHS dataset used in this study provides important variables to study, a number of factors remain unmeasured. Households report important variables such as their drinking water sources and type of sanitation, but researchers did not verify their responses, test water quality, or determine all water sources used by the participants. However, using available variables, this analysis indicated that childhood diarrhea in Peru likely has multiple causes with geographic, socioeconomic, type of drinking water, and type of sanitation being important factors. Further investigation into the 25 Peruvian states show that while diarrhea prevention is needed on a national level, five states in Peru with the most dramatically elevated rates of diarrhea and two additional states that have slightly elevated rates should be the focus of interventions and/or prevention efforts (Table 2). Interestingly, among seven states, access to improved sanitation and water, as well as poverty rates vary quite dramatically. Furthermore, several other states have unimproved sanitation and unimproved drinking water distribution similar to these seven, but have fewer cases of diarrhea. These drastic differences and inconsistencies across states make it difficult to come to any concrete conclusion and begs the question: what is driving these elevated rates?

It seems that natural region is the primary factor predicting diarrhea risk, as well as type of drinking water, specifically for those living in the rainforest natural region. Analysis of diarrhea rate by sanitation and water access stratified by natural region also suggests that having unimproved sanitation in the rainforest region exacerbates the health outcome. Wealth is also a significant factor predicting diarrhea risk, however it is correlated with natural region. Specifically, the rainforest region of Peru has the highest rate of diarrhea and the highest proportion of poor people. Additionally, a majority of the participants in the study are poor. The sierra also appeared to have higher rates of under five diarrhea, however this elevated prevalence was not as dramatic. As with many diseases, further research of Peruvian natural regions and states suggest that multifactorial causes of diarrheal diseases could be at play due to differing rates of diarrhea among the states within the rainforest natural region.

While general poverty and lack of improved access to water and sanitation are factors in relation to child diarrhea, living in the rainforest appears to be the major factor. Yet dramatic inconsistencies across states both in regards to diarrhea rates, poverty, water and sanitation access within the rainforest natural region seems to suggest that other causes not found within the available data may be contributing to childhood diarrhea. As Peru's major industry is natural resource extraction, there are frequent news reports and studies investigating industrial exposure and environmental contamination. Loreto has a high poverty rate, as well as high unimproved sanitation and drinking water rates, but this state is known for the vast number of oil blocks and subsequent water contamination that remain unmeasured in this study [20]. Reports from 2011 show that there were at least 90 oil spills over 3 years in northern Peru's Amazon rainforest [21]. Additionally, other studies in the area found increased blood lead levels among the population [22]. These factors could account for elevated rates of diarrhea in Loreto, as well as in Amazonas and San Martín. Furthermore, if contamination is occurring, diarrhea could be a symptom of exposure and more severe health outcomes.

In regards to Junin and Pasco, oil and other industries have been found to lead to major environmental contamination. Junin is known for some oil blocks, as well as nonferrous metal smelting, steel mills, and hydroelectric centers. Research has found lead, arsenic, and cadmium contamination due to nonferrous metal smelting in La Oroya, Peru, a city in Junin around 2012, when the DHS data from this analysis was collected [23]. This city has been regarded as one of the most polluted places on earth [24]. Pasco has comparable pollution problems from mining, specifically in the city of Cerro de Pasco. This town is being overtaken by an open-pit mine. Research from 2009 concluded that potentially 1.6 million people in Peru could be exposed to lead in soil due to these mining practices [25]. Similar issues with petroleum and mining contamination have been found in Ucayali and Apurímac [26, 27]. With that said, efforts to improve water and sanitation may be resulting in insignificant changes to child health due to industrial contamination.

This study differs in focus from other research presented on determinants of childhood diarrhea. Many findings using similar databases and statistical approaches link childhood diarrhea to maternal education, the age of the mother, and rural-urban residence [28, 29]. While these variables were significant in initial analyses, when put in the final logistic regression model, they were either insignificant or did not contribute to the overall fit of the model. Overall, it appears that these differences in findings may be linked to the unique geographic and industrial situations in Peru, as well as other unknowns.

While the industrial contamination piece of this argument is suggestive, other studies and news reports seem to corroborate that many citizens of Peru are suffering from deleterious environmental exposures from mining and oil industries. Although this data is from 2012, mining and oil operations have continued to develop over the past 5 years. Specifically, over 70% of the Peruvian Amazon is now open for oil and gas drilling and/or exploration [30]. Furthermore, in 2016, a number of oil spills were reported and the Peruvian government has declared of number of emergencies related to mining and petroleum contaminations [20, 21, 26, 27]. Peru has focused much effort in the past 20 years on improvement of water and sanitation infrastructure, however other environmental issues may be decreasing the effectiveness of improved infrastructure and should therefore be the focus of interventions. More research, policies, and protection for Peruvian citizens is of immediate need, especially for those areas that have higher poverty rates, have less access to improved water and sanitation, and are at high risk of industrial environmental exposure. Future research should be performed using DHS GPS data that is available for Peru and more recent data, which has potential to support the findings and conclusions found in this study. Additionally, evaluation of water and sanitation quality would also be useful in order to determine the pathways responsible for child diarrhea.

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Appendix

Table 1a: Study Population Family and Child Characteristics by Under Five Diarrhea

	Total N=9449	**DIARRHEA** N=1254 (13.3%)	**NO DIARRHEA** N=8154 (86.7%)	**P-value**
Wealth Index				
Poor	5328 (56.4%)	783 (14.7%)	4545 (85.3%)	
Middle	1,919 (20.3%)	265 (13.8%)	1654 (86.2%)	p<0.0001
Rich	2,201 (23.3%)	206 (9.5%)	1995 (90.5%)	
Mother's Education Level				
None	345 (3.7%)	37 (10.7%)	308 (89.3%)	
Primary	3002 (31.8%)	386 (12.9%)	2616 (87.1%)	p<0.0001
Secondary	4102 (43.4%)	620 (15.1%)	3482 (84.9%)	
Higher	1959 (20.7%)	211 (10.8%)	1748 (89.2%)	
Father's Education Level				
None	123 (1.3%)	16 (13.0%)	107 (87.0%)	
Primary	2246 (23.8%)	302 (13.5%)	1944 (86.6%)	p=0.0246
Secondary	5636 (59.6%)	782 (13.9%)	4854 (86.1%)	
Higher	864 (9.1%)	87 (10.1%)	777 (89.9%)	
Mother's Age				
<20	625 (6.6%)	124 (19.8%)	501 (80.2%)	
20-29	4283 (45.3%)	657 (15.3%)	3626 (84.7%)	p<0.0001
30-39	3554 (37.6%)	377 (10.6%)	3177 (89.4%)	
40-49	946 (10.0%)	96 (10.2%)	850 (89.9%)	
Father's Age				
<20	68 (0.7%)	13 (19.1%)	55 (80.9%)	
20-29	2621 (27.7%)	410 (15.6%)	2211 (84.4%)	
30-39	3601 (38.1%)	432 (12.0%)	3169 (88%)	p=0.0001
40-49	1507 (15.9%)	174 (11.6%)	1333 (88.5%)	
50-59	300 (3.2%)	34 (11.3%)	266 (88.7%)	
>59	52 (0.6%)	7 (13.5%)	45 (86.5%)	
Number of household members				
Mean (SD)	5.5 (2.1)	5.7 (2.4)	5.5 (2.1)	
Median (Q1, Q3)	5.0 (4, 7)	5.0 (4, 7)	5.0 (4, 7)	p=0.0016
(Min, Max)	(1, 19)	(1, 19)	(1, 19)	
Current Age of Child				
<6 months	845 (8.9%)	95 (11.1%)	750 (88.8%)	
6-11 months	934 (9.9%)	166 (17.8%)	768 (82.2%)	
12-23 months	1846 (19.5%)	395 (21.4%)	1451 (78.6%)	p<0.0001
24-35 months	1951 (20.6%)	277 (14.2%)	1674 (85.8%)	
36-47 months	1901 (20.1%)	190 (10.0%)	1711 (90.0%)	
48-59 months	1,856 (19.6%)	124 (6.7%)	1732 (93.3%)	
Sex of Child				
Male	4768 (50.5%)	662 (13.9%)	4106 (86.1%)	p=0.1083
Female	4640 (49.1%)	592 (12.8%)	4048 (87.2%)	
Disposal of Child's Stools				
Unsafe	4697 (49.7%)	726 (15.5%)	3971 (84.5%)	p<0.0001
Safe	4546 (48.1%)	500 (11.0%)	4046 (89.0%)	

Table 1b: Study Population Geographic Characteristics by Under Five Diarrhea

	Total N=9449	DIARRHEA N=1254 (13.3%)	NO DIARRHEA N=8154 (86.7%)	P-value
Type of residence				
Urban	5463 (57.8%)	700 (12.8%)	4763 (87.2%)	p=0.0834
Rural	3945 (41.8%)	554 (14.0%)	3391 (86.0%)	
Natural Region				
Lima Metro	689 (7.3%)	79 (11.5%)	610 (88.5%)	
Coast	2388 (25.3%)	220 (9.2%)	2168 (90.8%)	p<0.0001
Sierra	3634 (38.5%)	417 (11.5%)	3217 (88.5%)	
Rainforest	2697 (28.5%)	538 (20.0%)	2159 (80.0%)	

Table 1c: Study Population Water and Sanitation Characteristics by Under 5 Diarrhea

	Total N=9449	DIARRHEA N=1254 (13.3%)	NO DIARRHEA N=8154 (86.7%)	P-value
Water Treated Before Drinking				
No	1771 (18.7%)	272 (15.4%)	1499 (84.7%)	p=0.0053
Yes	7637 (80.8%)	982 (12.9%)	6655 (87.1%)	
Source of Drinking Water				
Unimproved	1043 (11.0%)	198 (19.0%)	845 (81.0%)	p<0.0001
Improved	7449 (78.8%)	915 (12.3%)	6534 (87.7%)	
Type of Toilet Facility				
Unimproved	2428 (25.7%)	380 (15.6%)	2048 (84.4%)	p<0.0001
Improved	6668 (70.6%)	813 (12.2%)	5855 (87.8%)	

Table 2: Descriptive statistics for Peruvian States

Peruvian State	Natural Region(s)	Diarrhea rate by Region	Unimproved Sanitation (%)	Unimproved Water (%)	Poverty Rate [36] (%)	Major Industry
Amazonas	Sierra, Rainforest	30/161, 56/271	23.4	16.0	47.3	Agriculture; Petroleum [31]
Ancash	Coast, Sierra	17/141, 39/260	23.3	1.6	23.5	Copper Mining[37]
Apurímac	Sierra	43/302	30.2	4.1	42.8	Metal mining [37]
Arequipa	Coast, Sierra	3/57, 17/247	9.5	7.0	9.1	Textiles [38]
Ayacucho	Sierra, Rainforest	49/392, 3/32	25.1	3.4	51.9	Silver/gold Mining [37]
Cajamarca	Sierra, Rainforest	18/277, 9/105	18.3	4.6	52.9	Gold mining [37]
Callao	Lima Metro	8/80	10.7	4.2	-*	Fish; Port [38]
Cusco	Sierra, Rainforest	24/217, 6/42	32.1	3.5	18.8	Textiles [38]
Huancavelica	Sierra	35/343	29.5	5.8	46.6	Cinnabar mining
Huánuco	Sierra, Rainforest	24/297, 15/73	27.4	13.6	40.1	Agriculture [38]
Ica	Coast	35/358	20.9	6.7	4.7	Agriculture
Junin	Sierra, Rainforest	30/191, 30/109	26.6	2.2	19.5	Metal Smelting [32]; Copper mining [37]
La Libertad	Coast, Sierra	10/265, 8/148	15.3	3.3	29.5	Silver mining [37]
Lambayeque	Coast, Sierra	25/316, 1/15	24.7	9.7	24.7	Agriculture [38]
Lima	Lima Metro, Coast, Sierra	71/609, 7/60, 2/32	18.6	6.8	13.1	Trade; Industry
Loreto	Rainforest	184/612	50.1	48.1	37.4	Petroleum [31]
Madre de Dios	Rainforest	50/431	39.4	21.3	3.8	Gold mining; Logging [37]
Moquegua	Coast, Sierra	12/176, 4/40	9.4	6.7	8.7	Agriculture [38]
Pasco	Sierra, Rainforest	46/297, 30/132	48.8	8.2	46.6	Lead Mining; ore processing; smelting [33, 34, 37]
Piura	Coast, Sierra	44/424, 9/68	31.4	11.1	35.1	Agriculture
Puno	Sierra, Rainforest	32/318, 4/18	35.7	3.0	32.4	Agriculture
San Martín	Rainforest	82/411	22.1	21.2	30.0	Petroleum [31]
Tacna	Coast, Sierra	25/213, 6/29	16.5	10.8	11.8	Gold mining [37]
Tumbes	Coast	42/378	20.5	19.1	12.7	Agriculture [38]
Ucayali	Rainforest	69/461	25.9	35.1	13.4	Petroleum; Agriculture [31, 35]

*Poverty rate for Callao was not available, however the region is similar to Lima in regards to industry and economy.

Table 3a: Rate (%) of Under Five Diarrhea in Lima Metropolitan Natural Region by Sanitation and Water Access

	Unimproved Sanitation	Improved Sanitation
Unimproved Water	16.7	15.0
Improved Water	15.7	10.4

Table 3b: Rate (%) of Under Five Diarrhea in Coastal Natural Region by Sanitation and Water Access

	Unimproved Sanitation	Improved Sanitation
Unimproved Water	8.3	4.9
Improved Water	10.0	9.4

Table 3c: Rate (%) of Under Five Diarrhea in Sierra Natural Region by Sanitation and Water Access

	Unimproved Sanitation	Improved Sanitation
Unimproved Water	24.1	4.6
Improved Water	12.6	10.7

Table 3d: Rate (%) of Under Five Diarrhea in Rainforest Natural Region by Sanitation and Water Access

	Unimproved Sanitation	Improved Sanitation
Unimproved Water	31.5	21.0
Improved Water	17.5	17.9

Table 4: Bivariate Analysis of Diarrhea in Children Under Five

Predictor	Odds Ratio	95% CI	P-value	Predictor	Odds Ratio	95% CI	P-value
Sanitation Access:				**Drinking Water Access:**			
Unimproved	-	-		Unimproved	-	-	
Improved	0.75	(0.66, 0.85)	<0.0001	Improved	0.60	(0.50, 0.71)	<0.0001
Water Treated:				**Type of Residence:**			
No	-	-	-	Rural	-	-	
Yes	0.81	(0.70, 0.94)	0.0053	Urban	0.90	(0.80, 1.01)	0.0835
Natural Region:				**Wealth Index:**			
Rainforest	-	-					
Lima metro	0.52	(0.40, 0.67)	<0.0001	Poor	-	-	
Coast	0.41	(0.34, 0.48)	<0.0001	Middle	0.93	(0.80, 1.08)	0.3437
Sierra	0.52	(0.45, 0.60)	<0.0001	Rich	0.61	(0.52, 0.72)	<0.0001
Sex of Child:							
Male	-	-		**Number of Household Members**	1.04	(1.02, 1.07)	0.0016
Female	0.91	(0.81, 1.02)	0.1084				
Current Age of Child (months):				**Disposal of Child's Stool:**			
48-59	-	-					
36-47	1.55	(1.23, 1.96)	0.0003				
24-35	2.31	(1.85, 2.89)	<0.0001	Unsafe	-	-	
12-23	3.80	(3.07, 4.71)	<0.0001	Safe	0.68	(0.60, 0.76)	<0.0001
6-11	3.02	(2.36, 3.87)	<0.0001				
<6	1.77	(1.34, 2.34)	<0.0001				
Mother's Age:				**Mother's Education:**			
<20	-	-					
20-29	0.73	(0.59, 0.91)	0.0042	None	-	-	
30-39	0.48	(0.38, 0.60)	<0.0001	Primary	1.23	(0.86, 1.76)	0.2598
40-49	0.46	(0.34, 0.61)	<0.0001	Secondary	1.48	(1.04, 2.11)	0.0283
				Higher	1.01	(0.69, 1.45)	0.9797
Father's Age:				**Father's Education:**			
<20	-	-					
20-29	0.79	(0.43, 1.45)	0.4382	None	-	-	
30-39	0.58	(0.31, 1.06)	0.0783	Primary	1.04	(0.61, 1.78)	0.8897
40-49	0.55	(0.30, 1.03)	0.0625	Secondary	1.08	(0.63, 1.83)	0.7831
50-59	0.54	(0.27, 1.09)	0.0861	Higher	0.75	(0.42, 1.33)	0.3209
>59	0.66	(0.24, 1.79)	0.4121				

Table 5: Modification of the Effect of Natural Region on Under Five Child Diarrhea by Drinking Water Access

	Lima Metro		Coast		Sierra		Rainforest	
	Diarrhea rate	OR (95% CI)	Diarrhea rate	OR (95% CI)	Diarrhea rate	OR (95% CI)	Diarrhea rate	OR (95% CI)
Unimproved Source	7/46	1.43 (0.62, 3.33)	12/210	0.48 (0.26, 0.91)*	17/141	1.09 (0.62, 1.93)	162/646	2.67 (1.96, 3.64)*
Improved Source	67/601	1.00	185/1943	0.84 (0.62, 1.13)	358/3185	1.01 (0.77, 1.33)	305/1415	1.72 (1.30, 2.28)*

*p-value<0.05

Table 6: Multiple Logistic Regression of Diarrhea in Children Under Five

Predictor	Odds Ratio	95% CI	P-value	Predictor	Odds Ratio	95% CI	P-value
Sanitation Access:				**Disposal of Child's Stool:**			
Unimproved	-	-		Unsafe	-	-	
Improved	0.85	(0.74, 0.99)	0.0027	Safe	0.87	(0.75, 1.01)	0.0642
Current Age of Child (months):				**Drinking Water Access * Natural Region:**			
				Lima metro Improved	-	-	
48-59	-	-		Lima metro Unimproved	1.44	(0.61, 3.40)	0.4039
36-47	1.52	(1.19, 1.96)	0.0009	Coast Improved	0.87	(0.65, 1.18)	0.3711
24-35	2.18	(1.73, 2.76)	<0.0001	Coast Unimproved	0.48	(0.25, 0.92)	0.0257
12-23	3.47	(2.75, 4.38)	<0.0001	Sierra Improved	1.03	(0.78, 1.36)	0.8450
6-11	2.56	(1.94, 3.37)	<0.0001	Sierra Unimproved	1.13	(0.64, 2.02)	0.6700
<6	1.58	(1.16, 2.16)	0.0038	Rainforest Improved	1.78	(1.33, 2.38)	<0.0001
				Rainforest Unimproved	2.62	(1.90, 3.60)	<0.0001

*Hosmer and Lemeshow Goodness-of-Fit Test P-value=0.1933

Image 1: Map of Peru

Acknowledgements

As this project is meant to be the culmination of the graduate school degree, it seems fitting to recognize that every person I have interacted with, learned from, and been mentored by have assisted me through this journey. First and foremost, I would like to thank my chair and mentor, Dr. Wayne Sanderson, for his guidance, encouragement, and constant willingness to collaborate. I would also like thank my other committee members, Dr. Steve Browning and Dr. Kathleen Winter for their time and energy regarding this project. Finally, I would like to thank my friends and family for their support in all my endeavors, academic or otherwise.

I have no financial or material supports to disclose for this project.

Biographical Sketch

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