HOW TROPICAL CYCLONES AFFECT POST-NATAL CARE IN MADAGASCAR. AN ANALYTIC STUDY USING MARGINAL STRUCTURAL MODELS (MSMs)

by

DAWSON DOBASH

(Under the Direction of Allan Tate)

ABSTRACT

Post-natal care can be scarce within low-/middle-income countries (LMIC) and could be even more scarce following natural disasters. Using Marginal Structural Models (MSMs) and Demographic and Health Surveys (DHS) from 2003-2004 and 2008-2009 in Madagascar, we modeled the effect that tropical cyclones have on delivery places and personnel, polio 0 vaccines and vitamin A doses, health professional checking the health of the baby and mother after birth, and the size of the baby. We also tested the suitability of MSMs to control for selection processes.

Based on logistic regressions and results from the 2008-2009 DHS, there is a need for more post-natal care after a disaster hits. Patients were less likely to see hospital/health center deliveries with a professional assisting the delivery, and receive Polio 0 vaccines and vitamin A doses in the post-disaster period.

INDEX WORDS: Post-natal care, Low/middle-income countries, Marginal Structural Models (MSM), Deliveries, Polio 0, Vitamin A, Baby, Madagascar, Demographic and Health Surveys (DHS)

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CHAPTER 1

BACKGROUND

Disaster Effects on Regular Care

Disasters can affect society in various ways, but damage to healthcare can be especially devastating. For example, when Hurricane Katrina struck the United States in 2005, many hospitals and nursing homes were damaged, and some destroyed. [1] This led to many injuries among employees and a total of 215 patients and residents died. Hurricane Katrina struck so quickly that some communities were not able to evacuate before the flooding from the hurricane. Healthcare supplies may also be either lost or compromised. When Puerto Rico was struck by Hurricane Maria in 2017, pharmacies were severely damaged, and some destroyed.[2] Consequently, patients' medications and other prescriptions were destroyed or unable to be used which caused a shortage especially for temperature sensitive medications. This supply shortage spread throughout the country over a short period of time.

Within low-/middle-income countries (LMIC), the effects of natural disasters can be more severe. For Madagascar, as of 2021, 60% of the country was inaccessible,[3] and the availability for healthcare workers of these areas was scarce. This leads to a limited number of healthcare workers and an uneven geographic spread of care. In early 2004, Tropical Cyclone Elita severely damaged 510 schools and hospitals.[4] Major road closures due to flooding, trees blocking traffic, or road damage may also have prevented health care supplies from reaching people that were affected by the tropical cyclone. Medicines and medical kits[5] throughout the whole country of Madagascar were needed to be able to give the residents enough care.

After Typhoon Bopha struck the Philippines in 2012, response teams came to their aid. They settled in rural and remote areas of the Philippines where the closest hospital from their location was around 4 hours by road. However, the road itself was compromised due to the typhoon. A destroyed bridge was discovered that left most transportation of critically ill patients unavailable to local hospitals.[6] The response teams gave as much aid as they could with their limited technology and supplies without having access to a hospital. In a similar example, many cyclones hit Madagascar in early 2007 leading to health centers not receiving supplies that usually come bi-monthly. [7] This was a result of road damage which disrupted transportation of essential supplies.

Disaster Effects on Post-natal Care

Mothers with newborns are particularly sensitive to disasters.[8] Giving the best care for these mothers and their babies during their delivery and the months after giving birth is important to increase their chances of living a normal healthy life during the period of disaster recovery.

Within high-income countries, there are still major concerns about the availability of post-natal care after a disaster strikes. These consist of the displacement of mothers from their primary care and their doctors who were planning on delivering the mother's child. Health care professionals who normally prepare for deliveries are given other responsibilities such as disaster recovery, and supplies of post-natal supplements are compromised. Badakhsh[9] conducted a study which included interviews of 11 women who were pregnant during Hurricane Katrina and who were not permanently displaced out of areas of Louisiana and their homes. This study was conducted to help understand how Hurricane Katrina affected pregnant women during and after their pregnancy. Hurricane Katrina affected Louisiana greatly and of those who gave birth in

Baton Rouge, Louisiana, there were some concerns about the availability of hospital staff to assist with deliveries due to the influx of patients from Hurricane Katrina based on the interview responses. Standard services were not available due to Hurricane Katrina such as personnel for deliveries. Although these women volunteered to participate in the interviews, the experiences of each of these women showed there was disruption of deliveries and post-natal care.

Women in low-/middle-income countries (LMIC) may also take the role as the primary caregiver for their whole family while the husband works[8] to provide for the family. This additional responsibility could put stress on the mother and their baby. Mothers with newborns or those who are about to give birth need supplements, care, and mental calmness to reduce the stress on them and their babies since stress could have adverse consequences for the baby. Stress on women who are about to give birth could cause low infant birth weight, preterm delivery, or gestational diabetes[10] depending on how long the stress has been occurring. After catastrophic events such as natural disasters, emergency relief should include coaching and emotional support to new mothers to make sure they keep calm during chaotic times. If the mother does not have food, water, or a safe place for her and her baby especially for breastfeeding, disaster relief teams aim to find a safe place for them and provide them with the resources they need.[11] Following the 2010 earthquake in Haiti, 60 pregnant women were studied[12] to help improve health care for new mothers. The women who had deliveries were all homeless and living under tents. Many cases of adult and neonatal tetanus surfaced in response to inadequate care. The accessibility of care should be present for all mothers.

Methodological Challenges in Disaster Public Health Research using Observational Data

The use of observational data in disaster public health is a way to test the effects of a disaster on a population. However, using observational data, no causal inferences can be made with absolute certainty. Causal inferences can be strengthened by controlling for the right confounders in the analysis. Although most disasters are seasonal and for some countries expected, it is hard to execute observational studies in determining the effects for these disasters. The logistics of conducting an observational study with large preparation would be very difficult on a research team if the natural disaster is the sole purpose of the study. Another difficulty that occurs in observational studies, specifically cross-sectional designs, is that previous knowledge and secular trends of the characteristics and the outcome of interest of the certain region in which the disaster affected could be hard to obtain.

Large-scale demographic and health surveys aim to achieve representative national samples. However, when a disaster occurs in the middle of planned data collection, a change of demographics and responses could follow the disaster which affects the results for surveys that do not take the disaster into account. Selection processes such as full displacement of people, people's willingness to participate, or just missing people of a certain population are some difficulties that can be encountered. This could introduce sampling bias and volunteer bias within the survey. Surveyors also tend to conduct surveys of randomly selected households/individuals in a convenient order to optimize efficiency of the survey process, rather than visiting selected households/individuals in a random order. Consequently, results of data analyses may be subject to sampling bias based on confounders from demographic differences among those who were surveyed before and after the disaster struck. Subpopulations may not be appropriately represented leading to sample compositional differences in the post-disaster period that can affect inference.

Since the occurrence of a disaster is random, unpredictable, and most surveys do not take into account for them, one could argue that a survey can serve as a natural experiment[13] if a disaster takes place while a survey is being conducted. Natural experiments could be argued as a way of potentially finding treatment effects in observational data similar to those using randomized trials.[14] Natural experiments, where a disaster occurs, treats the disaster as the exposure to the population, and the control is a pseudo-population of those who were not exposed to the disaster. Natural experiments that occur within surveys might not show equal representation in the control and experimental groups as selection processes could occur which alter the representation.

Marginal Structural Models (MSMs) can be used to control for selection biases attributed to the impact of the natural disasters on the survey process. MSMs are used to control for confounding that occur within the selection process by using Inverse Probability Weights (IPWs). In our application, we will adjust for demographic variables to create an appropriate population comparison between the pre-disaster and post-disaster periods.

A similar approach that helps control for confounding and selection bias in observational data is Propensity Score Matching (PSM). PSMs allow for unbiased estimators of treatment effects by adjusting for confounding. PSMs use logistic regression to create these propensity scores that are probabilities of receiving the exposure. PSMs, however, have some limitations. PSM techniques have to consider residual confounding bias. The true propensity scores will never be known, and therefore no one will know the true effect and accuracy of PSMs. PSMs do not take into account of unknown confounders. PSMs will not work well in smaller datasets as this technique requires matching participants and some participants may not match well which could affect the effectiveness of PSMs.[15] Another major limitation is that PSMs should be used on nonrandom exposures.[16] Since natural disasters are random events and PSMs use nonrandom exposures within the analysis, MSMs will be considered over PSMs in this study.

In this thesis, we will use marginal structural models (MSM) to address selection processes which produce confounders that occur due to tropical cyclones in a cross-sectional population study in Madagascar. We will compare two populations, one in the pre-disaster period and one in the post-disaster period. MSMs will help adjust demographics in both periods to obtain a comparable study between the two periods to determine how the disaster affected post-natal care.

Aim of Research

The current study examines how tropical cyclones affect post-natal care. This includes delivery place and personnel, vitamin A supplement and polio 0 vaccine accessibility, health assessment for baby and mother by a health professional, and the size of the baby at birth. We expect the tropical cyclones will have a negative impact to post-natal care. Accessibility of vitamin A supplements and polio 0 vaccines will decrease post-disaster. The delivery place and personnel will be less likely to be in a hospital or health center with a health professional assisting in the delivery. It will also be less likely for a health professional assessing the health of the baby and mother within the post-disaster. Small newborns with low birthweights will have a higher proportion in the post-disaster. The results from this study will give Madagascar more insight on if better preparation of supplies and personnel for deliveries and post-natal care is needed or if it is already sufficient when a disaster hits the country. This information could also give similar Low-/Middle-Income Countries (LMIC) that are affected by disasters seasonally knowledge on different ways to increase their preparation and possibly adopt these techniques.

The current study will also examine if Marginal Structural Models (MSMs) are suitable to study disaster effects within survey and observational data that are affected by selection processes. We hypothesize MSMs will deliver a more effective non-bias comparison controlling for selection process confounders compared to the raw data and using the survey weighting provided by the survey that is used to give a nationally represented sample. The MSMs will control for confounding that was not considered in creating the survey weights.

CHAPTER 2

METHODS

DHS Survey of Madagascar

Demographic and Health Surveys (DHS) are nationally representative household surveys that are administered in Low-/Middle-Income Countries (LMIC) through funding provided by USAID and country Ministries of Health. DHS surveys started in 1984 and have been used within over 90 LMIC[17] throughout central America, south America, Africa, and Asia. Every five years, the DHS program updates the questionnaire. Updating DHS every five years create viable questions specific to the situations that occur throughout the years, and possibly throw out questions that might not be relevant. This allows DHS to be an ideal source of data for participating LMICs. Having a representative sample for these LMICs is important as the amount of resources to conduct national surveys might be too costly. DHS use updated and relevant questions for the populations they survey to receive information that will help each country. DHS questionnaires are flexible as countries can request country-specific questions into their surveys or include country-specific answer choices. DHS have multiple questionnaires that pertain to certain subpopulations. The main questionnaires are for households, women, and men. Within the individual questionnaires, topics such as fertility, reproductive health, nutrition, HIV/AIDS, nutrition, and many other topics are covered.[18,19]

Two DHS datasets administered in Madagascar were identified during which several tropical cyclones occurred while the study was in the field during survey years 2003-2004 and 2008-2009. The data collection was conducted by the Institut National de la Statistique (INSTAT) for both the 2003-2004 and 2008-2009 DHS surveys. For the survey of 2003-2004, data collection occurred from November 2003 to March 2004. There was a total of 8,420 households and 7,949 women[18] of the ages 15-49 were sampled. The 2008-2009 survey was conducted between November 2008 and August 2009 where 17,857 households and 17,375 women[19] between the ages 15- 49 were surveyed. Unpooled analyses will be conducted to compare the pre-disaster period in 2003-2004 with the post-disaster period in 2003-2004. A similar replicate analysis will compare the pre-disaster period to the post-disaster period in 2008-2009. Both of these analyses will be based on the birth's recoded data set which provides information about each woman's full birth history. This includes information on pregnancy, postnatal care, immunization, and health of the child for children born in the last five years. The specific questionnaire versions used for the 2003-2004 and 2008-2009 surveys were phases 4 and 5, respectively.

All DHS surveys follow a probability-based sampling design to obtain a representative sample of each country's population. Specifically for Madagascar, two-stage household-based random sampling surveys are conducted. In the first stage Madagascar was partitioned into geographic clusters called enumeration blocks which comprise the primary sampling units (PSUs). The PSUs were stratified by urban and rural areas, and the strata helps identify the randomly selected PSUs by systematic probability sampling where each PSU has an equal chance of being chosen. Within each of the randomly selected PSUs, roughly 30-35 households were randomly selected.

For the 2003-2004 survey, these clusters were defined based on the 1996 master sample which in turn was based on the 1993 housing census.[18] There was a total of 760 enumeration blocks used as the PSUs. These enumeration blocks were later classified into four different types of areas within each of the six provinces of Madagascar (Table A1). These areas include the capital, rural, Other Major Urban Centers (OMUC), and Secondary Urban Centers (SUC).[18] These four different areas within each province were used to create a total of 19 strata. A total of 174 PSUs were randomly selected using a systematic sampling within each stratum where each PSU has an equal probability of being sampled. Of the 174 PSUs, 119 were in urban PSUs and 55 in rural PSUs. In the second stage of the survey, a total of 5,306 households were selected[18] for the women's survey using simple random sampling. Of the selected households, 1,777 were rural households, Of the two major prevention areas of Antananarivo and Fianarantsoa, around the same number of rural households were surveyed in these two provinces. For this survey, it was known that there was an overrepresentation of urban households compared to rural households.[18]

For the 2008-2009 survey, the latest census taken was still the 1993 census, but it was considered too old to use for this survey. Therefore, the DHS program used results from the cartography prepared for the 2009 census[19] to inform the sampling strategy. From the cartography, a total of 21,835 enumeration blocks were identified to be used as the PSUs. These enumeration blocks are classified using 23 regions instead of the six provinces, and by a newly defined urban and rural areas of study (Table A2). The combination of the 23 regions and the residence types creates the sampling strata. Therefore, a total of 43 sampling strata were identified since some regions did not host an urban or rural residence type. A stratified sample of 600 PSUs were identified with a probability proportional to the size of each PSU. Of the PSUs selected, 149 were urban residence, and 451 were rural residences. In the second stage of the survey, a total of 19,200 households were selected using simple random sample where 14,432 of these households were rural households.[19]

In both surveys, most households were pre-selected[20] instead of being selected when the DHS surveyors arrived in Madagascar. This was done to reduce convenience bias in the field study. In a DHS survey, the household sampling probabilities depend on the number of households in each of the sampled PSUs. For the number of households sampled in each PSU, there is a weighting scheme used for its population.

However, when a disaster hits in the middle of survey collection, selection biases such as full displacement of people from their homes and the area they reside in, and people's willingness to participate due to mental and physical distress are introduced. Another problem that occurs is that representation of characteristics may not be split equally between those who are surveyed before and after a disaster strikes. Surveyors randomly sample households that are within a certain proximity before traversing into other areas such as another province or district to limit the time to perform the surveys. One problem that could occur is that surveyors might have surveyed, for example, most of the rural sections/regions of the country first and then leave most of the urban areas last or vice-versa. If a disaster occurs in the middle of survey collection, the split of characteristics could be polarizing as the pre-disaster population could be more rural and the post-disaster could be more urban, or one region could have been only surveyed before or after the disaster struck. DHS surveys do not modify their sampling strategy when an unplanned event occurs during the middle of survey collection. This characteristic of DHS surveys is mostly considered a strength due to the consistency of surveys and easier comparability of different surveys, but it could be a limitation such as in this previous example.

Population

The data source for this analysis is Demographic and Health Surveys (DHS) within Madagascar. We will be focusing on two DHS surveys that occurred in 2003-2004 and 2008-

2009. Within the 2003-2004 Madagascar survey, two major tropical cyclones occurred, tropical cyclone Elita (01/28/04) and Gafilo (03/07/04). The post-disaster period is identified by any mother who was surveyed after the date 01/28/04. Those who are considered pre-disaster are mothers who are surveyed before 01/28/04 because they were not affected by either tropical cyclone. The cutoff of the comparison group is tropical cyclone Elita instead of Gafilo because no mixed effects should be observed with the non-exposed group which is the pre-disaster. Those who are exposed to at least one tropical cyclone are still hindered from a disaster impact.

The pre-disaster subsample for the 2003-2004 survey will be mothers who have given birth within six months prior to responding to the survey. Six months is chosen to minimize mixing of previous cyclone season effects. For the post-disaster subsample, the baby should be born in February 2004 or later because within the DHS data set, information on the birth of the baby only includes the month and year, and not day. Restricting the birth of a baby after January will guarantee no cross-over of mothers between pre- and post-disaster periods since tropical cyclone Elita occurred in January. After implementing the restriction criteria and only using complete cases, the analytic sample for the 2003-2004 Madagascar survey includes 310 observations where 285 are in the pre-disaster and 25 in the post-disaster. The unequal split is due to the timing of the first tropical cyclone in accordance to the survey collection period.

In the 2008-2009 survey, tropical cyclones Eric (01/19/09), Fanele (01/21/09), and Jade (04/06/09) struck Madagascar in the middle of survey collection. For reasons similar to the 2003-2004 analysis, we will use tropical cyclone Eric to determine the pre- and post-disaster periods. Mothers who were surveyed before 01/19/09 will be considered the pre-disaster period while those who were surveyed after will be considered the post-disaster period.

The restriction of mothers who have given birth within six months prior to responding to the survey will be used in the pre-disaster sample. For the post-disaster sample, it will be restricted to mothers that have given birth in February 2009 or later and responded to the survey after tropical cyclone Eric (01/19/09). Similar to the 2003-2004 survey, since tropical cyclone Eric occurred in January, babies born in February or later will be affected by the tropical cyclone and no cross-over should occur. Based on the restrictions and criteria, 399 observations, where 225 in the pre-disaster and 174 in the post-disaster, is observed for the 2008-2009 Madagascar survey. In summary, the size of the two analytic samples were 310 and 399 respectively, and 8.1% and 43.4% were observed in the post-period after applying all inclusion and exclusion criteria.

Measures

Outcomes

For each outcome except for polio 0, those who are eligible to answer the following questions are mothers who has given birth within the past 5 years or 60 months prior to the interview. The eligibility for polio 0 vaccine at birth is all children born within the past 5 years or 60 months prior to the interview.

Delivery place asks the mother, “where did you give birth to (NAME)?” The mother can report on ‘your home’, ‘other home’, ‘government hospital’, ‘government health center’, ‘government health post’, ‘other public (specify)’, ‘private hospital/clinic’, ‘other private medical (specify)’, or ‘other (specify)’. The variable indicator within the dataset was ‘M15’. Four major classifications within the original question are considered, homes, public sector, private sector, and other. Of the specific responses that were within the analytic sample, ‘government hospital’, ‘government health center’, and ‘private health center’ were combined and collapsed to create the category of 'hospitals and health centers', 'Respondent's home' and 'other home' were combined to create 'home'. A 'hospital and health center' delivery binary variable was created where 'home' deliveries is the reference group.

Professional assisting in delivery is a variable that asks the type of person who participated in the delivery process of the baby. This outcome should also be considered along with the delivery place outcome because although deliveries that occur in hospitals or health centers will have professional assistance, that outcome will not capture those who have professional assistance at home births. The delivery place outcome focuses on the infrastructure and equipment problems due to the tropical cyclones while the professional assisting in delivery outcome focuses on disturbance on professional health care personnel in the country of Madagascar. From the survey, mothers were asked, "who assisted with the delivery of (NAME)?" The options were 'doctor', 'nurse/midwife', 'auxiliary midwife', 'traditional birth attendant', 'trained birth attendant', 'relative/friend', 'other (specify)', or 'no one'. This question was split up into multiple sub-variables shown as the variables 'M3A-M3N' in the dataset. Of these, options of various professional and personnel positions are considered. For the options specific to the sample in use, a dummy variable called professional assisted deliveries was created to determine if a professional assisted in the delivery or not. Within the professional assistance category, 'doctor', 'nurse/midwife', and 'trained birth attendant' were combined while all other categories were collapsed into the 'non-professional or no assistance' category. The reference group is 'non-professional or no assistance'.

Size of child is a variable within the dataset that was determined by subjective responses of the mother. Each mother was asked, "when (NAME) was born, was he/she very large, larger than average, average, smaller than average, or very small." The variable in the dataset was

'M18'. To help reduce the smaller frequency groups, a new ordinal category of three levels was created 'small', 'average', and 'large'. The 'small' category combines 'very small' and 'smaller than average' while the 'large' category combines 'very large' and 'larger than average'. 'Average' and 'large' will be contrasted against the 'small' reference group. To verify if *size of child* is a good representation of the baby's size, means and standard deviations of the observed birthweights by self-reported child size are displayed in Table 1. In the 2003-2004 sample, self-reported small-sized babies have a mean birth weight of 2.52 kg with a standard deviation of 0.608 compared to average-sized babies having an average birth weight of 2.95 kg with a standard deviation of 0.371. Similarly, in the 2008-2009 sample, small-sized babies have a mean weight of 2.52 kg with a standard deviation of 0.545 compared to average-sized babies having a mean birth weight of 2.94 kg with a standard deviation of 0.361. The birthweight variable is available in the dataset but is not used due to a large number of missing data in the survey.

Table 1: Size of child vs. Mean Birth Weight (in Kilograms)

Size of child		Small	Average	Large
Birth weight	2003-2004 survey	2.520 (0.608)	2.950 (0.371)	3.440 (0.378)
	2008-2009 survey	2.520 (0.545)	2.940 (0.361)	3.390 (0.503)

Health professional checking health after birth for mother and baby is a question that asked mothers, "after (NAME) was born, did a health professional or traditional birth attendant check your health?" The question was a 'yes' or 'no' question. This question only considered the mother's last birth in the past 60 months. This question is used only in the 2003-2004 survey as the 2008-2009 survey does not include it. The variable within the dataset is 'M50' of the 2003-2004 dataset. The answer of 'no' will be the reference group in the analysis.

Polio 0 vaccine for baby at birth is a variable in the dataset where the mother on the survey could have filled out the vaccination date on the vaccination card for polio 0, or by answering on a select all that apply question where the answers were "polio vaccine, that is, drops in the mouth" and a follow-up question of "when was the first polio vaccine received, just after birth or later." Those who answered just after birth would be their baby receiving polio 0. The variable identifier within the dataset is 'H0'. The original options on the dataset were 'no', 'vaccination date on card', 'reported by mother', and 'vaccination marked on card'. A receipt of polio 0 vaccine variable was created that determines if the baby did receive polio 0 at birth. If the respondent answered 'vaccination date on card', 'reported by mother', or 'vaccination marked on card', it will be considered 'yes', and 'no' otherwise. 'No' will be the reference level.

Vitamin A dose for mother within the first two months after delivery is specific to the mother and only considered for the last birth within the 60 months prior to the interview. Mothers were asked "in the first two months after delivery, did you receive a vitamin A dose?" This variable is a binary variable where the answers consist of 'yes' and 'no'. The variable identifier in the dataset is 'M54', and the reference group is 'no'.

Combining variable levels to reduce low frequency levels helped create an analytic dataset. It also avoided separation issues[21] within multinomial analyses. If low frequencies within variables occur during analyses, coefficients may be driven to plus or minus infinity when separation occurs or have high standard errors even in the absence of separation. This could make results hard to interpret or uninterpretable.

Predictor Variables

The pre- post-disaster indicator variable is the primary exposure variable for analysis of disaster effects. Demographic predictor variables were used to generate inverse probability weights (IPWs) and used as confounders in modeling the post-natal care outcomes within the third analytic strategy.

Pre- Post-disaster indicator is a variable created based on if the mother responded to the survey before or after the disaster struck Madagascar. For the 2003-2004 survey, mothers who responded to the survey before tropical cyclone Elita (01/28/04) will be considered pre-disaster, and post-disaster otherwise. For the 2008-2009 survey, mothers who responded to the survey before tropical cyclone Eric (01/19/09) will be considered pre-disaster, and post-disaster otherwise. Pre-disaster will be given a value of 0, and 1 for post-disaster. Pre-disaster will also act as the reference group.

Residence type was collected on the household questionnaire indicating if the respondent lived in ‘urban’ or ‘rural’ residence. In the dataset, the identifier is ‘V025’, and the reference group is ‘urban’ residence.

Province is a multi-level indicator of which province/region the respondent resides in. This information was collected on the household questionnaire under the indicator ‘region’. Within the raw dataset, the variable identifier is ‘V024’. For the 2003-2004 survey, six levels were identified where each one is considered a province in Madagascar. These levels range from values of 1-5 and 7. The value of 7 was recoded to 6 to avoid the jump between 5 and 7. For the 2008-2009 survey, the province variable was broken up into smaller regions ranging from values of 10 to 80. However, these regions were coded within larger groups which were the six provinces described in the 2003-2004 survey. Therefore, regions 10-19 were recoded to 1, 20-29 to 2, 30-39 to 3, 40-49 to 4, 50-59 to 5, and 70-79 to 6. The reference group is region/province 1.

Wealth index was collected on the household questionnaire as an indicator that determines which wealth category each respondent would be considered in. The original categories in the identifier of ‘V701’ in the dataset had five levels ranging from ‘very poor’, ‘poor’, ‘middle’, ‘rich’, and ‘very rich’. We recoded the five levels to three levels, ‘poor’, ‘middle’, and ‘rich’ by combining ‘very poor’ and ‘poor’ as well as ‘rich’ and ‘very rich’. The ‘poor’ wealth index is the reference group.

Partner’s Education is a question that asks the respondent, “what is the highest level of school (NAME) has attended?” This was asked for each person in the household that was being sampled. The options for this question were ‘no education’, ‘primary’, ‘secondary’, ‘higher’, or ‘don’t know’. In the raw dataset, where it was is called ‘V701’, there is a variable specific to the partner’s education. This variable is condensed by combining ‘higher’ and ‘secondary’ due to the low frequency of the higher education level. ‘No education’ is the reference group for this variable.

Electricity is a binary indicator variable where in the survey the respondent was asked, “does your household have electricity?” The answers were ‘yes’ or ‘no’. Within the dataset, the variable was under the name ‘V119’. The reference group for the electricity variable is ‘no’.

Transportation is a variable based on a question that asks, “does anyone of your household own: ‘A bicycle?’, ‘A motorcycle or motor scooter?’, or ‘A car or truck?’. The respondent can answer each question separately. Therefore within the data set, three different variables ‘V123’, ‘V124’, and ‘V125’ were identified. The variables were combined into a dummy variable which indicates if the respondent has no transportation or some transportation.

If the respondent has at least one of following modes of transportation, the respondent was ‘yes’, and ‘no’ otherwise. The reference group is ‘no’.

Floor material of respondent’s home is a variable that describes the floor material of the respondent’s home. Within the DHS survey, the floor material was based on observation by the surveyor. Specific floor materials can be chosen such as from the natural floor category, ‘earth/sand’ or ‘dung’, within the rudimentary floor category, ‘wood planks’ or ‘palm/bamboo’, within the finished floor category, ‘parquet or polished wood’, ‘vinyl or asphalt strips’, ‘ceramic tiles’, ‘cement’, or ‘carpet’, and ‘other’ which would be specified and put within the respected floor category. Using the three main categories of natural floor, rudimentary floor, and finished floor, the floor material variable will be collapsed and created to be used in the analysis. Within the dataset, the respected variable that describes this floor material is ‘V127’. Responses between values 10 to 19 are considered natural material, 20-29 are rudimentary material, and finished material otherwise. ‘Natural floor’ is the reference group.

Data Cleaning

Data cleaning consists of recoding the original variables to obtain an analytic data set. It also includes recoding ‘don’t know’ values from the survey to missing values to remove any values that will not assist in the analysis. The missing values from these observations for variables used in each specific model created will be removed from the analysis to only model observations with all available information. Some variables used in the analysis also need to be adjusted for such as the survey weights in the dataset. The survey weights, provided in the Demographic and Health Survey (DHS) dataset under the variable ‘V005’, must be divided by 1 million as required by the DHS guidelines[22]. This will allow for the survey weights to fully represent the population.

Statistical Methods

When a disaster strikes during a survey, selection bias may occur because the participants surveyed may not be representative of the population either before or after the disaster due to selection processes. The survey weights implemented in the survey itself are used to estimate parameters of the whole population. However, if a disaster occurs during collection, post-stratification of the population using a post-disaster indicator may result in biased estimates of demographic parameters. Marginal Structural Models (MSMs) will help control for the confounding effects of these demographic variables using inverse probability weights (IPWs).[13] They may also be used to adjust for bias for outcome-related dropout.[23]

MSMs assume exchangeability, consistency, positivity, and no misspecification of the model used to estimate weights. Exchangeability assumes that there are no unmeasured confounding variables that are correlated with both treatments and outcomes. Exchangeability cannot be verified based on observed data but can only be ensured through thorough identification of important confounders and an appropriately carried out analysis. Consistency is the assumption where the observed outcome for each observation is equal to the causal outcome based on the person's risk factors and their observed treatment history. Positivity is the assumption that there is a positive, non-zero, and non-perfect probability for each participant receiving each level of exposure. The treatment must be covered over every combination of covariates. For the assumption of no misspecification of the model, the model used in creating the inverse probability weights and the post-natal outcome models must be specified and correctly implemented.[24, 25, 26]

A survey design is created for the sample which is comprised of survey weights, primary sampling units (PSU), and strata all provided by the survey. An application of an option that allows the survey design to be used for strata that only have one PSU is applied. This adjustment centers the data from each stratum that only have one PSU around the grand mean of all of the strata. This survey design will be used within survey-weighted generalized linear modeling where a logistic regression model of a binary outcome is created to estimate probabilities of an observation being in the post-disaster based on demographic variables

$$logit(p_i) = X_i\beta \quad (1)$$

where p_i is the probability of the outcome being observed, X_i is a row vector of the predictor variables, and β is the coefficients corresponding to the association between the predictors and the outcome.

The parameters are estimated by maximizing the quasi-likelihood:

$$Q(\beta) = \sum_{i=1}^{n} w_i\{Y_i log p_i(\beta) + (1 - Y_i) log[1 - p_i(\beta)]\} \quad (2)$$

where w_i are the individual survey weights applied to each observation, Y_i are the observed binary outcomes, $p_i(\beta)$ is the probability of observing the outcome, and n is the total number of observations.

These quasibinomial likelihoods were used to predict probabilities that observations occurred in the post-disaster, which were in turn utilized to create the non-stabilized inverse probability weights (IPWs) for each observation

$$w_{1j} = \frac{1}{1-\widehat{P_j}} \quad \text{and} \quad w_{2j} = \frac{1}{\widehat{P_j}} \quad (3)$$

where w_{1j} is the weight for a pre-disaster observation, w_{2j} is the weight for a post-disaster observation, and $\widehat{P_j} = p_j(\hat{\beta})$ is the predicted probability of an observation being observed in the post-disaster.

Demographic variables that show large differences in proportions between pre- and post-disaster periods will be used in the survey-weighted generalized linear models to create the

IPWs. In choosing the demographic variables, the 2003-2004 survey data is used. The following demographic variables were considered to be included in creating the IPWs: residence type, province, wealth index, partner's education, having electricity, having transportation, and floor material of the respondent's home. A saturated logistic regression model, using the survey-weighted generalized linear modeling, including all seven demographic variables is created to model the post-disaster indicator variable. A correlation matrix was used to address potential multicollinearity in the data, see Figure A1. The correlation matrix helped determine if some predictors should be removed in creating the IPW values. The variables that had high correlation will be tested and removed from models to see if better estimates of IPWs are created. After considering the correlation matrix, two variables were identified with the strongest correlations between multiple variables, wealth index and having electricity. Four logistic regression models using the survey-weighted generalized linear modeling were created. IPW distributions were computed for the five models, and some large standard errors and weights were observed in the post-disaster sample (Table B1). This information shown in Table B1 gives valuable knowledge in determining if overall some subpopulations were over or under-represented by the survey. This will also indicate how much adjustment each IPW model is doing to the sample, and those that have large weights and IPW standard errors will raise questions on the validity of those certain models. The province variable had multiple small frequencies. In other demographic variables, small frequency levels were combined but there was no way to combine levels as each province is unique. By removing this variable from the IPW modeling, smaller IPW standard errors and means were achieved. Four additional logistic regression models were created in which all four did not include the variable province. These were created after understanding the impact of province to the weights. Nine sets of IPWs were created, each corresponding to a different model, and the sum of squared differences for weighted proportions based on the pseudo-population of each IPW weighted sample was computed (Table B1). The same nine sets of IPWs were created within the 2008-2009 DHS data as well to test if other combinations of variables and covariates will create more comparable groups for this specific data. The sum of squared weighted differences was calculated by

$$SSWD = \sum_{k=1}^{q} u_{jk}\left(d_{1jk} - d_{2jk}\right)^2 \quad (4)$$

where d_{1jk} and d_{2jk} are respectively the pre-disaster and post-disaster proportions of a specific level j of variable k, u_{jk} is the raw proportion of level j of variable k, and q is the total number of variables used in a particular IPW model. These weighted differences will be summarized for each IPW model. The IPW used for analysis will be determined by the lowest sum of squared weighted difference.

Logistic regression models implemented with the minimum SSWD IPW, using the ‘glm’ function in R, were fitted by maximizing the quasibinomial objective function for all of the binary outcomes, and a quasi-multinomial objective function for the size of child variable as it had three levels. The multinomial model uses the ‘multinom’ function. All models used complete cases of the respective variables used in each model. Three modeling strategies were performed to evaluate effect consistency given the various modeling assumptions. The first strategy compares each outcome to the pre- post-disaster indicator using the survey weights provided by the survey itself. The second strategy compares each outcome to the pre- post-disaster indicator using the selected inverse probability weights (IPWs). The final strategy evaluated the inclusion of confounder variables to act as additional adjustment for the pre- post-disaster indicator while using the IPW weights. The confounder variables included are the variables that created the selected IPWs for the analysis. They were used to determine if the IPWs alone adjusted enough for the demographic and covariates.

A comparison between the model using survey weights to the model using IPWs alone will determine if IPWs model the samples fruitfully. This will be done by determining if both models reflect a similar effect of tropical cyclones on the post-natal care outcomes. If the IPW model shows an opposite effect to what the survey weights show, IPWs might not have worked well for that specific outcome. The third analytic model of adding additional confounders will be used as a sensitivity analysis to the model using IPWs alone. The coefficients for the post-disaster indicator variable were used to compute odds ratios and corresponding 95% confidence intervals for each outcome.

The packages used within R to run these processes are: ‘survey’, ‘questionr’, and ‘nnet’. Within the ‘survey’ package, we used the function ‘surveydesign’ to create the survey design of each survey and ‘surveyglm’ to create the IPW model. Within the ‘questionr’ package, we used the ‘wtd.table’ function to create the proportions based on the nine different inverse probability weights (IPWs). The ‘nnet’ package was used to for the ‘multinom’ function to create the multinomial models for the size of child outcome.

CHAPTER 3

RESULTS

Sample Demographic and Outcome Characteristics

Tropical cyclones struck Madagascar in the middle of survey collection in both the 2003-2004 and 2008-2009 Demographic and Health Surveys (DHS). Table 2 describes the demographic distributions within the 2003-2004 and 2008-2009 DHS surveys. The distributions are based on the analytic samples selected in each survey. Large differences of demographics between pre- and post-disaster periods are observed. In the 2003-2004 Madagascar sample, more mothers with newborns in the post-disaster were observed in urban areas, region 1 of the survey, having a rich wealth index, having higher education, having electricity, having some transportation, and having more finished floor material for their home compared to the pre-disaster sample. Within the 2008-2009 data, there are some discrepancies between the regions surveyed as region 1 was surveyed more in the pre-disaster, more rural mothers within the post-disaster, and more poor wealth indexed mothers observed within the post-disaster period. Between the two surveys, larger differences are observed in the 2003-2004 survey but in both surveys, there are differences between the samples that were affected by the disaster. The type of residence for the 2008-2009 survey, regardless of before or after the disaster, shows large proportions within the rural setting, 74.2% and 83.3% for pre- and post-disaster respectively. Within the 2003-2004 survey, specifically in the post-disaster, only 32% of mothers were within rural residence. A large difference is shown in the partners education variable where around 48% of people have secondary or higher education in the post-disaster period compared to 23.2% in the pre-disaster of the 2003-2004 survey. In both the 2003-2004 and 2008-2009 survey samples, the province variable shows the largest differences where some provinces were sampled more in the pre-disaster and vice-versa.

Table 2: Demographic Distributions of Mothers with Newborns in the 2003-2004 and 2008-2009 DHS Surveys

		2003-2004 Survey		2008-2009 Survey	
		Pre-disaster (n=285)	Post-disaster (n=25)	Pre-disaster (n=225)	Post-disaster (n=174)
		Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Type of residence	Urban	114 (40.0%)	17 (68.0%)	58 (25.8%)	29 (16.7%)
	Rural	171 (60.0%)	8 (32.0%)	167 (74.2%)	145 (83.3%)
Province	Region 1	42 (14.7%)	15 (60.0%)	95 (42.2%)	12 (6.9%)
	Region 2	68 (23.9%)	1 (4.0%)	48 (21.3%)	41 (23.6%)
	Region 3	53 (18.6%)	5 (20.0%)	14 (6.2%)	17 (9.8%)
	Region 4	35 (12.3%)	1 (4.0%)	30 (13.3%)	62 (35.6%)
	Region 5	45 (15.8%)	1 (4.0%)	27 (12.0%)	37 (21.3%)
	Region 6	42 (14.7%)	2 (8.0%)	11 (4.9%)	5 (2.9%)
Wealth Index	Poor	136 (47.7%)	4 (16.0%)	86 (38.2%)	108 (62.1%)
	Middle	56 (19.6%)	7 (28.0%)	41 (18.2%)	19 (10.9%)
	Rich	93 (32.6%)	14 (56.0%)	98 (43.6%)	47 (27.0%)
Partners Education	No education	73 (25.6%)	3 (12.0%)	43 (21.4%)	57 (37.0%)
	Primary	146 (51.2%)	10 (40.0%)	96 (47.8%)	58 (37.7%)
	Secondary or higher	66 (23.2%)	12 (48.0%)	62 (30.8%)	39 (25.3%)
	Missing	0	0	24	20
Electricity	No	245 (86.3%)	16 (64.0%)	176 (79.6%)	149 (88.7%)
	Yes	39 (13.7%)	9 (36.0%)	45 (20.4%)	19 (11.3%)
	Missing	0	0	4	6
Transportation	No Transportation	243 (85.3%)	15 (60.0%)	177 (78.7%)	142 (81.6%)
	Some Transportation	42 (14.7%)	10 (40.0%)	48 (21.3%)	232 (18.4%)
Floor material within respondent's home	Natural	49 (17.2%)	3 (12.0%)	39 (17.3%)	30 (17.2%)
	Rudimentary	190 (66.7%)	9 (36.0%)	120 (53.3%)	115 (66.1%)
	Finished	46 (16.1%)	13 (52.0%)	66 (29.3%)	29 (16.7%)

Table 3 describes the raw outcome distributions for the analytic sample for both the 2003-2004 and 2008-2009 DHS surveys. According to the 2003-2004 survey, fewer hospital/health center deliveries, professional assisted deliveries, and health professional checks on health of baby and mother occurred in the pre-disaster. Polio 0 vaccination is also less prevalent in the pre-disaster compared to the post-disaster. There were more average-sized children born in the pre-disaster compared to the post-disaster; 31.2% and 16% respectively. The prevalence of vitamin A doses was similar where 17.1% of mothers received it in the pre-disaster and 20% in the post-disaster. In the 2008-2009 survey, hospital/health center deliveries and professional deliveries were less frequent in the post-disaster compared to the pre-disaster. Similarly, vitamin A doses and polio 0 vaccination were less prevalent in the post-disaster compared to the pre-disaster period. The sizes of the baby at birth were similar between the pre- and post-disaster samples. The 2003-2004 survey shows an increase in prevalence of care from the pre-disaster to the post-disaster based on the outcomes in Table 3. On the other hand, the 2008-2009 survey shows a decrease in prevalence of care from the pre-disaster to post-disaster.

Weighted Sample Demographic Characteristics

The selected demographic variables used to create the IPWs, after considering all variables, was selected by the IPW model with the lowest sum of squared weighted differences (SSWD). For the 2003-2004 DHS, these include type of residence, wealth index, partner's education, floor material of respondent's household, and owning a transportation vehicle (Table B1). This combination of variables created a SSWD of 0.165. For the 2008-2009 DHS, type of residence, province, floor material of respondent's household, and owning a transportation vehicle were used to create the lowest SSWD IPW, SSWD = 0.027. The worst performing IPW from the 2008-2009 sample had an SSWD of 0.132 which uses variables type of residence,

Table 3: Outcome distributions of the 2003-2004 and 2008-2009 DHS Surveys

		2003-2004 Survey		2008-2009 Survey	
		Pre-disaster Frequency (%) (n=285)	Post-disaster Frequency (%) (n=25)	Pre-disaster Frequency (%) (n=225)	Post-disaster Frequency (%) (n=174)
Place of delivery	Home delivery*	192 (67.6%)	14 (56.0%)	140 (62.2%)	132 (76.3%)
	Hospital/ health center	92 (32.4%)	11 (44.0%)	85 (37.8%)	41 (23.7%)
	Missing	1	0	0	1
Professional assisted delivery	No *	137 (48.1%)	8 (32.0%)	78 (34.7%)	104 (59.8%)
	Yes	148 (51.9%)	17 (68.0%)	147 (65.3%)	70 (40.2%)
Size of Child at birth (subjective)	Small *	74 (26.0%)	9 (36.0%)	56 (25.5%)	37 (21.5%)
	Average	89 (31.2%)	4 (16.0%)	90 (40.9%)	83 (48.3%)
	Large	122 (42.8%)	12 (48.0%)	74 (33.6%)	52 (30.2%)
	Missing	0	0	5	2
After birth, mother and baby received a check by a health professional	No *	115 (60.8%)	7 (50.0%)	Not Measured	Not Measured
	Yes	74 (39.2%)	7 (50.0%)		
	Missing	96	11		
Polio 0 vaccine for baby (at birth)	No *	198 (69.5%)	14 (56.0%)	140 (62.2%)	152 (87.4%)
	Yes	87 (30.5%)	11 (44.0%)	85 (37.8%)	22 (12.6%)
	Missing	0	0	0	5
Vitamin A dose for mother in first 2 months	No *	233 (82.9%)	20 (80.0%)	152 (68.2%)	142 (84.0%)
	Yes	48 (17.1%)	5 (20.0%)	71 (31.8%)	27 (16.0%)
	Missing	4	0	2	0

* reference groups in analysis

partner' education, having electricity, owning a transportation vehicle, and floor material of respondent's household. The combination of variables that created the median SSWD (0.095) of all nine IPWs tested for the 2008-2009 sample included type of residence, owning a transportation vehicle, and floor material of respondent's household. This shows how the 2003-

2004 sample had very large differences and the IPWs were not able to create the groups as similar as the 2008-2009 sample.

Tables 4 and 5 compares the raw, survey weighted, and IPW weighted frequency percentages of all seven demographic variables considered in creating the IPWs for both the 2003-2004 and 2008-2009 surveys. The use of the IPWs decreased the differences between estimates of pre- and post-disaster percentages. However, there are still some discrepancies and limited changes to certain variables.

Most of the adjustment by the IPWs was within the post-disaster period as fewer mothers were observed in this period compared to the pre-disaster for the 2003-2004 survey (Table 4). Some variables that did not adjust well using the IPWs were province and floor material. Region 1 in the post-disaster shifted farther away from the pre-disaster where in the raw percentages, 14.7% and 60%, and in the IPW percentages, 14.8% and 73.1% for the pre- and post-disaster periods, respectively. Similarly, in the floor material variable, the IPW tried to correct the finished floor material level where the percent difference between the post- and pre-disaster periods are 35.9% to 11.1% for the raw and IPW percentages, respectively. This resulted in a shift in the natural floor material where the percent difference between the post- and pre-disaster was -5.2% to 14.8% for the raw and IPW percentages, respectively. These large shifts could be due to the IPW not working well or the IPW identifying different levels of variables which needed less weight to give a practical representation for these subpopulations.

Table 4: Demographics of Mothers with Newborns within 2003-2004 Madagascar Survey (raw, survey weighted, and IPW weighted frequency percentages)

		Raw Percentages		Survey Weighted Percentages		IPW Weighted Percentages		Absolute Percentages Difference		
		Pre-disaster	Post-disaster	Pre-disaster	Post-disaster	Pre-disaster	Post-disaster	Raw	Survey	IPW
Type of residence	Urban	40.0%	68.0%	12.8%	24.3%	40.2%	50.2%	28.0%	11.5%	10.0%
	Rural	60.0%	32.0%	87.2%	75.7%	59.8%	49.8%	28.0%	11.5%	10.0%
Province	Region 1	14.7%	60.0%	13.4%	51.0%	14.8%	73.1%	45.3%	37.6%	58.3%
	Region 2	23.9%	4.0%	31.4%	1.4%	23.5%	1.2%	19.9%	30.0%	22.3%
	Region 3	18.6%	20.0%	20.4%	20.2%	18.8%	6.0%	1.4%	0.2%	12.8%
	Region 4	12.3%	4.0%	11.7%	9.2%	12.2%	13.3%	8.3%	2.5%	1.1%
	Region 5	15.8%	4.0%	14.6%	1.3%	16.0%	4.4%	11.8%	13.3%	11.6%
	Region 6	14.7%	8.0%	8.4%	16.9%	14.8%	2.0%	6.7%	8.5%	12.8%
Wealth Index	Poor	47.7%	16.0%	57.3%	36.8%	47.8%	42.8%	31.7%	20.5%	5.0%
	Middle	19.6%	28.0%	21.8%	43.3%	19.5%	17.0%	8.4%	21.5%	2.5%
	Rich	32.6%	56.0%	20.9%	19.9%	32.7%	40.2%	23.4%	1.0%	7.5%
Partners Education	No education	25.6%	12.0%	30.7%	26.0%	25.7%	25.2%	13.6%	4.7%	0.5%
	Primary	51.2%	40.0%	55.2%	54.5%	51.2%	46.5%	11.2%	0.7%	4.7%
	Secondary or higher	23.2%	48.0%	14.1%	19.5%	23.1%	28.3%	24.8%	5.4%	5.2%
Electricity	No	86.3%	64.0%	93.2%	89.2%	86.3%	75.5%	22.3%	4.0%	10.8%
	Yes	13.7%	36.0%	6.8%	10.8%	13.7%	24.5%	22.3%	4.0%	10.8%
Transportation	No Transportation	85.3%	60.0%	91.2%	71.7%	85.3%	75.2%	25.3%	19.5%	10.1%
	Some Transportation	14.7%	40.0%	8.8%	28.3%	14.7%	24.8%	25.3%	19.5%	10.1%
Floor Material	Natural	17.2%	12.0%	15.7%	35.7%	17.4%	32.2%	5.2%	20.0%	14.8%
	Rudimentary	66.7%	36.0%	74.0%	41.0%	66.4%	40.4%	30.7%	33.0%	26.0%
	Finished	16.1%	52.0%	10.2%	23.3%	16.2%	27.3%	35.9%	13.1%	11.1%

Table 5: Demographics of Mothers with Newborns within 2008-2009 Madagascar Survey (raw, survey weighted, and IPW weighted frequency percentages)

		Raw Percentages		Survey Weighted Percentages		IPW Weighted Percentages		Absolute Percentage Difference		
		Pre-disaster	Post-disaster	Pre-disaster	Post-disaster	Pre-disaster	Post-disaster	Raw	Survey	IPW
Type of residence	Urban	25.8%	16.7%	15.7%	12.3%	22.3%	20.2%	9.1%	3.4%	2.1%
	Rural	74.2%	83.3%	84.3%	87.7%	77.7%	79.8%	9.1%	3.4%	2.1%
Province	Region 1	42.2%	6.9%	41.7%	16.8%	32.0%	13.9%	35.3%	24.9%	18.1%
	Region 2	21.3%	23.6%	21.3%	24.8%	22.8%	24.6%	2.3%	3.5%	1.8%
	Region 3	6.2%	9.8%	8.6%	17.1%	8.5%	7.4%	3.6%	8.5%	1.1%
	Region 4	13.3%	35.6%	9.3%	22.7%	19.6%	24.6%	22.3%	13.4%	5.0%
	Region 5	12.0%	21.3%	12.4%	17.0%	13.6%	21.3%	9.3%	4.6%	7.7%
	Region 6	4.9%	2.9%	6.6%	1.7%	3.4%	8.2%	2.0%	4.9%	4.8%
Wealth Index	Poor	38.2%	62.1%	33.6%	57.0%	43.8%	56.7%	23.9%	23.4%	12.9%
	Middle	18.2%	10.9%	21.6%	13.2%	18.1%	11.6%	7.3%	8.4%	6.5%
	Rich	43.6%	27.0%	44.7%	29.7%	38.0%	31.7%	16.6%	15.0%	6.3%
Partners Education	No education	21.4%	37.0%	16.7%	26.2%	23.5%	30.4%	15.6%	9.5%	6.9%
	Primary	47.8%	37.7%	52.6%	46.3%	47.8%	41.5%	10.1%	6.3%	6.3%
	Secondary or higher	30.8%	25.3%	30.6%	27.4%	28.7%	28.1%	5.5%	3.2%	0.6%
Electricity	No	79.6%	88.7%	83.0%	87.1%	82.8%	85.4%	9.1%	4.1%	2.6%
	Yes	20.4%	11.3%	17.0%	12.9%	17.2%	14.6%	9.1%	4.1%	2.6%
Transportation	No Transportation	78.7%	81.6%	77.7%	78.1%	80.3%	80.7%	2.9%	0.4%	0.4%
	Some Transportation	21.3%	18.4%	22.3%	21.9%	19.7%	19.3%	2.9%	0.4%	0.4%
Floor Material	Natural	17.3%	17.2%	17.4%	14.5%	16.2%	15.4%	0.1%	2.9%	0.8%
	Rudimentary	53.3%	66.1%	55.8%	69.2%	58.0%	63.5%	12.8%	13.4%	5.5%
	Finished	29.3%	16.7%	26.8%	16.3%	25.8%	21.1%	12.6%	10.5%	4.7%

Most variables did adjust well using IPWs in the 2008-2009 survey shown in Table 4. For example, the raw percentages of urban households reduced from 68% to 50.1% in the post-disaster to get closer to the pre-disaster percentage of around 40%. This showed an absolute percent difference change from 28% to 10% for the raw percentage and IPW percentage, respectively. The wealth index variable showed a large adjustment for the poor wealth index level in the post-disaster where in the raw percentage was 16% to an IPW weighted percentage of 42.8% to compare to the pre-disaster percent of poor wealth index of around 48%.

The survey weighted percentages in Table 4 show some different demographic spreads compared to what the raw percentages show. Rural residence in the post-disaster is only represented by 32% of mothers surveyed whereas using the survey weights, 75.7% reside in rural residence. This adjustment led to the majority, within both pre- and post-disaster, living in rural areas based on the survey weights. One variable that adjusted better using the survey weights instead of the IPW weights was electricity where percent difference between those who have electricity in the post-disaster compared to the pre-disaster is 4% using the survey weights compared to 10.8% using the IPWs. Although the survey weights created smaller differences for the demographic variables compared to the raw frequencies, the IPW weights did a better job in mitigating the differences.

Table 5 shows the IPW weighted percentages did create closer groupings for variable levels but the adjustment was not large. There was not much adjustment as the sample sizes were more equal and less discrepancies were shown in the raw percentages in the 2008-2009 sample compared to the 2003-2004 sample. The adjustment using the inverse probability weights (IPWs) happened within both the pre- and post-disaster in the 2008-2009. The largest adjustment occurred within the wealth index variable. Of mothers who are considered to have poor wealth index, the raw percentages showed a distribution of 38.2% and 62.1% while the IPW weights give percentages 43.8% and 56.7% for the pre-disaster and post-disaster periods, respectively. There were still some large differences within the province variable. Province 1 had an absolute difference within the raw proportions of 35.3% and using the IPWs, the absolute difference is now 18.1%. Although this is a large correction, this difference is still very large.

The differences between the pre- and post-disaster periods were more similar using the survey weights compared to the raw proportions. However, for the wealth index variable, there was not a lot of adjustment. The absolute percent difference for the rich wealth index are 16.6% and 15% for the raw and survey weighted proportions, respectively. Although the survey weights did create more comparable groups compared to the raw proportions, the IPWs did better in making comparison groups. As described above, the differences between the two periods for the wealth index variable did not change that much using the survey weights. However, using the IPWs, the difference was minimized for each level of wealth index.

Post-Natal Care Outcome Assessment

Table 6 displays the results of three methods of estimating odds ratios for the post-disaster indicator for each outcome. The first odds ratios created are using the post-disaster indicator variable with the survey weights. These odds ratios will be used to compare to using Inverse Probability Weights (IPWs) as described in the second column. The third model is a sensitivity analysis for using the IPWs. Confounder variables are added to the second analytic strategy of using IPWs to create adjusted odds ratios to determine if extra adjustment of these variables is needed that the weights itself did not capture.

Considering the 2003-2004 odds ratios based on the survey weights, no significant differences between pre- and post-disaster periods were observed. However, despite being insignificant, large associations are observed for the size of the child outcome. Odds ratio of 0.647 (95% CI, 0.229, 1.826) and 0.547 (95% CI, 0.200, 1.493) for average-sized babies and large-sized babies, respectively, suggest a high non-significant association that small-sized babies being born in the post-disaster are more likely. The 2008-2009 odds ratios using survey weights show odds ratios favoring less post-natal care in the post-disaster. The odds ratio of having hospital/health center deliveries is 0.470 (95% CI, 0.295, 0.737). The odds ratio of having professional assisted deliveries is 0.449 (95% CI, 0.295, 0.681). Therefore, home deliveries and non-professional assisted or non-assisted deliveries are around 2 to 2.5 times more likely to occur in the post-disaster compared to hospital/health center deliveries and professional assisted deliveries. Similarly, receipt of polio 0 vaccines and vitamin A doses within the first two months after delivery are less likely to occur in the post-disaster with odds ratios of 0.255 (95% CI, 0.148, 0.423) and 0.287 (95% CI, 0.159, 0.494), respectively.

Using IPWs and the post-disaster indicator as the predictor, professional assisted deliveries and health professional checking the health of the baby and mother is around 2.5 times more likely to occur in the post-disaster for the 2003-2004 survey, 2.351 (95% CI, 1.291, 4.277) and 2.532 (95% CI, 1.258, 5.226), respectively. Using IPWs, average-sized babies are more likely to be born compared to small-sized babies in the post-disaster; OR=1.581 (95% CI, 1.138, 2.195). With an odds ratio of 1.709 (95% CI, 0.925, 3.274), there is weak evidence suggesting that polio 0 vaccines are more likely to occur in the post-disaster. In the 2008-2009 survey, odds ratios using IPWs were more conservative than the survey weights where adjustment made odds ratios closer to a value of 1 with the exception of size of child. Hospital and health center deliveries became more conservative and non-significant with an odds ratio of 0.677 (95% CI, 0.441, 1.036). Professional assisted deliveries, polio 0 vaccines, and vitamin A doses are less likely to occur in the post-disaster period. Average-sized babies are more likely to occur during the post-disaster; OR = 1.526 (95% CI, 1.064, 2.187).

The third analytic modeling strategy created adjusted odds ratios based on using the IPWs. This analysis is used as a sensitivity analysis for IPWs. From the 2003-2004 sample, the additional adjustment created only one significant odds ratio for the outcome. There is 4.75 (95% CI, 1.297, 20.229) increased odds of a health professional checking the health of the mother and baby in the post-disaster compared to no health professional checking the health of the mother and baby. Large confidence intervals are also shown in the professional assisting a delivery outcome, 2.488 (95% CI, 0.641, 9.870). This describes a large non-significant association between professional assisted deliveries and the natural disaster. Due to these large errors which is based on a smaller sample size along with more covariates to adjust for, significant odds ratios are harder to be observed. Similar significant odds ratios were observed from using IPW weights alone but became not significant when additional adjustment occurred from the variables. The sensitivity analysis is underpowered especially for the 2003-2004 sample as too many covariates might be added in for certain models. In result, there was no calculation for the adjusted odds ratio of the vitamin A dose outcome as there was data sparsity issues. In the 2008-2009 sample, similar trends throughout the three models were shown. Although the odds ratios for the outcomes are consistent and still show home deliveries, non-professional assisted deliveries, less polio 0 vaccinations, and less vitamin A doses are more likely in the post-disaster, these odds ratios are going towards the null when adjusting for confounders with the exception of the outcome size of the child at birth. Overfitting might not be the reason for this as adding the confounders in the model did not create larger confidence intervals compared to only using the IPWs. Average-sized babies are more likely to be born compared to small-sized babies in the post-disaster based on the odds ratio of 1.569 (95% CI, 1.080, 2.278). After adjusting for the confounders and using IPW weights, it is 2 to 3 times less likely for professionals to assist in deliveries, receipt of Polio 0 vaccines, and receipt of vitamin A doses within the first two months after delivery to occur in the post-disaster. The adjusted odds ratios for professionals to assist in deliveries, receipt of Polio 0 vaccines, and receipt of vitamin A doses within the first two months after delivery are 0.444 (95% CI, 0.277, 0.706), 0.452 (95% CI, 0.258, 0.782), and 0.387 (95% CI, 0.222, 0.666), respectively.

Table 6: Model Estimations (odds ratios for pre- post-disaster indicator)

Outcomes		Survey Indicator	Odds Ratio (Using survey weights)	Odds Ratio (using IPWs)	Odds Ratio (adjusting for demographic variables and IPWs)
Hospital/health center delivery		2003-2004	0.793 (0.200, 2.402)	1.578 (0.858, 2.995)	1.104 (0.348, 3.492)
		2008-2009	**0.470 (0.295, 0.737)**	0.677 (0.441, 1.036)	0.721 (0.442, 1.175)
Professional Assisted in Delivery		2003-2004	1.070 (0.385, 2.872)	**2.351 (1.291, 4.277)**	2.488 (0.641, 9.870)
		2008-2009	**0.449 (0.295, 0.681)**	**0.446 (0.297, 0.667)**	**0.444 (0.277, 0.706)**
Size of Child	Average	2003-2004	0.647 (0.229, 1.826)	**1.581 (1.138, 2.195)**	1.619 (0.988, 2.652)
	Large		0.547 (0.200, 1.493)	1.247 (0.915, 1.701)	1.036 (0.706, 1.520)
	Average	2008-2009	1.476 (0.845, 2.577)	**1.526 (1.064, 2.187)**	**1.569 (1.080, 2.778)**
	Large		1.297 (0.724, 2.324)	1.268 (0.864, 1.862)	1.438 (0.961, 2.152)
After birth, mother and baby received a check by a health professional^		2003-2004	0.981 (0.263, 3.248)	**2.532 (1.258, 5.226)**	**4.755 (1.297, 20.229)**
Polio 0 vaccine for baby (at birth)		2003-2004	1.062 (0.296, 3.098)	1.709 (0.925, 3.274)	1.982 (0.213, 24.54)
		2008-2009	**0.255 (0.148, 0.423)**	**0.419 (0.262, 0.665)**	**0.452 (0.258, 0.782)**
Vitamin A dose for mother within the first 2 months		2003-2004	0.771 (0.127, 2.790)	1.154 (0.549, 2.658)	not estimable
		2008-2009	**0.287 (0.159, 0.494)**	**0.370 (0.224, 0.601)**	**0.387 (0.222, 0.666)**

Bold-faced values are significant at p < 0.05

*Reference group for size of child variable is a small-sized baby

^ After birth, health professional checked health is not a variable within the 2008-2009 survey

CHAPTER 4

DISCUSSION

The current study examined how tropical cyclones affected maternal and child health, specifically post-natal care, during two storm seasons in Madagascar. Results indicated post-natal assessments and care are less likely to occur after a disaster strikes the country based on the 2008-2009 Demographic and Health Survey (DHS). This includes the location of the deliveries, who assisted the deliveries, polio 0 vaccine availability, and vitamin A dose availability within the first two months of having their baby. Comparing the results of the 2003-2004 sample with the 2008-2009 sample, most results did not cohere with one another.

Based on the odds ratios using the inverse probability weights (IPWs), the 2003-2004 sample showed professional assisted deliveries and a health professional checking the health of the mother and baby after delivery were more likely to occur in the post-disaster period, and average-sized babies compared to small-sized babies are more likely to be born in the post-disaster. Based on a paper by Andersson[27] that studied health care delivery after hurricanes Katrina and Rita hit the United States, the hurricanes disrupted newborn screening and a small pause of operations for newborn screening occurred due to infrastructure damage and lack of equipment. This is consistent with how most disasters affect health care delivery systems by loss of infrastructure, accessibility of certain services, and resources of regular standard of care.[28] Although these results could be true for the 2003-2004 tropical cyclone season, delivery systems tend to be damaged on multiple levels. The results from this 2003-2004 Madagascar sample indicated a salutary effect of mothers and babies to receive a health check from a health professional after a disaster. This finding does not cohere with the findings described above and may be due to small sample size. There is also weak evidence of more hospital/health center deliveries and accessibility to polio 0 vaccines in the post-disaster. From an emergency appeal for support on February 27, 2004 by the Church World Service (CWS)[29], there was a call for aid that included $50,000 worth of supplies after tropical cyclone Elita hit in 2004. Damage of the cyclone included 55 damaged hospitals, and a request of essential items and medicines. Less than two weeks after this appeal was sent out, tropical cyclone Gafilo hit Madagascar and even worse damages occurred since they were in the middle of rebuilding. The reports of needing supplies and items around a month after tropical cyclone Elita hit and the damage to health facilities does not relate with the findings of the analysis on the 2003-2004 sample. Although the results from this analysis could be true, the reports from Madagascar during the following months of tropical cyclone Elita does not sound like they had an influx of aid in health care personnel and supplements, and the damages to hospitals would most likely promote deliveries to occur outside of hospital/health center buildings. The use of the 2008-2009 sample gives a more concerning message to the effects of the tropical cyclones on new mothers and their newborns where professional assisted deliveries, receipt of polio 0 vaccines, and receipt of vitamin A doses are less likely to occur after a disaster strikes. There is also weak evidence hospital and health center deliveries are less likely to occur in the post-disaster period. There is only one outcome that is consistent between the two samples, the size of the child at birth. Average-sized babies are more likely to be born in the post-disaster compared to small-sized babies. This shows a positive result as having an average-sized baby indicates a more healthy baby compared to small-sized or large-sized babies. However, the results from both of these samples are opposite to what most studies find[30, 31] where disasters negatively impact baby's birth weights and lower birth weights are more likely after a disaster strikes. These differences between the 2003-2004 and 2008-2009 samples could be truly observed by the impact of the tropical cyclones to the amount of disaster response received or pre-existing supplies. It also could be due to sample size limitations and not enough adjustment using the IPWs within the 2003-2004 sample.

The IPWs from Marginal Structural Models (MSMs) were used to help remove differences of demographic changes between the pre-disaster and post-disaster periods which occurred from selection processes. The main effects using survey weights differed with using IPWs within the 2003-2004 sample. Using the survey weights, the odds ratios suggest post-natal care is less likely in the post-disaster while the IPW weights suggest it is more likely in the post-disaster specifically for receipt of vitamin A doses, health professional checking health of mother and baby after birth, size of the baby, and hospital/health center deliveries. Since the pre- post-disaster main effects differ between survey weighting and IPW weighting, MSMs may be inappropriate for those respected outcomes in the 2003-2004 sample. MSMs might fail when large differences in demographic variables are observed, and when the natural experiment conditions are not met due to the timing of the tropical cyclone and the limited survey administration after it struck. The sensitivity analysis, which added confounders in the model, showed similar odds ratios to the IPW weights except for the health professional checking the health of mother and baby. These large differences could be shown by the sum of squared weighted difference (SSWD) values. The SSWD values for all nine IPWs tested in the 2003-2004 sample were larger than worst IPW’s SSWD created in the 2008-2009 sample. This shows a small sample size and the timing of the disaster can be a limitation to the usage of marginal structural models and satisfying exchangeability conditions. MSMs might not always be the best solution for selection bias as shown in the 2003-2004 sample. For the 2008-2009 sample, the results using survey weights and IPW weights cohered with one another. Slight adjustment towards a more conservative result using the IPW weights occurred. When adjustment of confounders were introduced by adding more variables to the model, even more conservative adjustments of the post-disaster main effect is seen with the exception of the size of child outcome. Comparing results of the three different models, all cohere with one another with no flipped effects. Therefore, MSMs were effective in modeling the post-disaster effect on post-natal outcomes in the 2008-2009 sample.

Care delivery systems for post-natal care was diminished after the tropical cyclones struck Madagascar according to the 2008-2009 sample. However, during mid-January of 2009, political tension started to arise. This led to public outbursts[32, 33] such as looting and destruction of property. Looting occurred not only in regular stores and warehouses but also the Malagasy Red Cross Society (MRCS) warehouse in Antsohihy[33] which supplied medical items and other aid. This affected the supply of medical services especially for women and children. The political tension and the outbursts that occurred created a hostile environment that made UNICEF hesitant[32] in giving aid to the people that was affected by the tropical cyclones. It was a challenge for these agencies to spread supplies which left thousands of people without any assistance from the cyclones. Therefore, the outcomes that are associated with supplements and vaccines were plausibly affected by the tropical cyclone and the joint underlying effects of a complex political crisis for the mothers that gave birth during this time.

After the tropical cyclones hit, deliveries occurring at home and non-healthcare professional assisted deliveries or non-assisted deliveries were more likely. More deliveries at home show possible infrastructure problems that occurred on hospital and health centers while the non-professional assistance or no assistence outcome shows a possible disruption to health care personnel to fulfill their necessary tasks due to the effects of the tropical cyclones. Although hospital deliveries are safer since they have all the resources needed there to keep the mother and baby healthy, home deliveries are more common in low-income such as Madagascar. Knowing there was weak evidence of an increased likelihood of having a home delivery and strong evidence of more non-professional aid in deliveries after a disaster strikes, a course of action in making home deliveries safer should be put in place as a more practical alternative to promoting hospital deliveries. In the low-/middle-income country (LMIC) of Tanzania, a study was conducted by Walraven[34] determining that more perinatal deaths occur at home deliveries compared to hospital deliveries, and one of their recommendations was for all births to be attended by trained personnel. With the knowledge from the 2008-2009 results and supporting arguments from the Tanzania study, a way to create a safer environment at home is having an abundance of professional assistance that would be able to travel to homes regularly, and more resources and supplies should be prepared and able to be accessed for these situations.[35,36] This could occur with more training of personnel and an introduction of supply vaults in small towns or villages. These supply vaults could have inventory of portable water to give hygiene to the mothers, delivery kits that could make the deliveries more sterile and safer, and post-natal supplements. These vaults will be very helpful for mothers who were planning on having a hospital delivery but was unable due to a catastrophic event such as a natural disaster.

The lack of supplements such as polio 0 vaccines and vitamin A doses in the first two months after delivery is also more likely in the post-disaster period. The combination of the tropical cyclones and the political crisis could have created this larger difference of supply between the pre- and post-disaster periods. In the 2008-2009 sample, less than 50% of the mothers in both the pre- and post-disaster periods did not have vitamin A doses. Vitamin A is a key component of breast milk which is how most infants get their nutrients from. The extra vitamin A doses are given to mothers to make sure there is enough nutrients[37] in their breast milk to give to their infants. From the results where vitamin A doses were less likely in the post-disaster period, this could be troublesome for mothers and their babies as they might not be able to give their child enough nutrients to be healthy and prevent health problems for the baby such as stunting. Breastmilk is known to decrease the odds of a child stunting.[38] Therefore, making sure the breastmilk of mothers is nutritional could prevent health conditions such as stunting. The polio 0 vaccine supply could have been majorly affected by the combination of the tropical cyclones and the political issues for the mothers who gave birth during the times of the political crisis. As mentioned before, UNICEF was hesitant to come into Madagascar to give aid and supplies to those who were affected by the disaster due to the looting and uproars occurring by the public[32, 33]. Therefore vaccines may not have been transported to the people in need immediately after the tropical cyclones struck, and the large effect size observed in this analysis might have been magnified substantially based on these problems of accessibility. The independent affects related to the political crisis and the tropical cyclone are not possible to disentangle from these data. Regardless, secure storage and equitable delivery of resources remains as an important approach to preserving the health of mothers and newborns during complex social and environmental disasters.

For future studies, specifically for the 2003-2004 DHS, a recommendation includes a small follow-up questionnaire after the disaster struck Madagascar for the mothers who responded to the DHS before the disaster struck. This will create a pseudo-longitudinal study to compare the accessibility of post-natal supplements, nutrition, and aid by health professionals. This type of future study would focus on disasters that occur near the end of survey administration so the compositional differences between the pre- and post-disaster samples will be controlled for. A future study that should be considered for the 2008-2009 DHS sample is looking at the impact of the gestational ages on birth outcomes in the post-disaster period. This is due to a long post-disaster period and the birth outcomes might differ based on how far along the mother is with her child when the tropical cyclone stuck Madagascar.

Strength and Limitations

Strengths

A strength to this study was the survey sources of Demographic and Health Surveys (DHS). DHS surveys have been a reliable source for low-/middle-income countries, and they used the same logistical elements administering DHS. In Madagascar, two-staged household sampling has been used for decades which allows for a consistent strategy and comparison between surveys. Another strength of this analysis is using multiple samples to determine if there is consistency of results. In the 2003-2004 sample, the results concluded that a possible influx of post-natal care occurred in the post-disaster period. If only tested in the one sample, we might have concluded no additional care or changes to health delivery services is needed. However, testing the additional 2008-2009 sample, we found opposite effects which encourages change to health delivery systems to increase post-natal care after the tropical cyclone struck. Considering only one sample could give the wrong recommendations to the population of Madagascar and other similar low-/middle-income countries. Another strength is showing when Marginal Structural Models are effective and when they might fail by using multiple samples. Within the 2003-2004 sample, the sample weights created opposite effects compared to the Inverse Probability Weights (IPWs). Therefore, testing another survey, 2008-2009 survey, that showed consistent effects of the tropical cyclones throughout the three model types gave a better look on how Marginal Structural Models (MSMs) worked. This revealed that MSMs were more effective in the 2008-2009 survey for the majority of outcomes compared to the 2003-2004 survey. The MSMs should give adjustment to the population that was underweighted or overweighted by the survey weights. Large differences in the 2003-2004 sample could have alluded to the opposite effects between the survey weights and IPWs. Therefore, testing the 2008-2009 sample that did not include large differences gave consistent results between the survey weights and IPWs with some adjustments. Since smaller differences in the 2008-2009 sample was present, the idea of a natural experiment is shown in comparing two groups of individuals that adjusted for confounders and in result gave comparable groups to find the effect of tropical cyclones on outcomes.

Limitations

A limitation of the 2003-2004 survey is the timing of the tropical cyclones itself. Tropical cyclone Elita was the first cyclone that struck Madagascar within the survey, and it occurred late January. As the DHS survey ended in March, the post-disaster period was limited to one and a half months. This led to a small sample size in the post-disaster period which also made corrections for subpopulation differences, based on MSMs, challenging. This can be shown with the opposing effects using survey weights and IPWs in Table 6. Since subpopulation differences were challenging to make comparable in the pre- and post-disaster periods, ideal natural experiment conditions were most likely not met. The small sample size also created larger confidence intervals for the odds ratios of outcomes specifically after birth health professional checked health, polio 0 vaccine, and professional assisted deliveries. The limited sample size, specifically in the post-disaster sample, also did not allow for an estimate for the vitamin A dose outcome since adding the confounders took too much power away from the model and not every combination of variables was found. Violation of the positivity assumption within this model could have occurred due to not observing all combinations. Another limitation was the amount of missingness for the outcome after birth mother and child received a health check by a health professional. This variable was not measured in the 2008-2009 survey which does not give the results from the 2003-2004 survey a comparison but, it also had 34% and 44% missingness of the analytic 2003-2004 sample (Table 3) in the pre- and post-disaster periods, respectively. This connects with the previous limitation of small sample size which could create a large confidence interval being observed on this outcome. This variable could have been taken out of the Demographic and Health Surveys (DHS) for the later phases as it was not answered often. The unmeasured confounding assumption might have been violated within the 2008-2009 analysis for the outcomes vitamin A dose and polio 0 vaccine. It might have been violated due to the additional political crisis that occurred around the same time as the tropical cyclones which gives uncertainty that the results reflect only from the tropical cyclone and not the political crisis which created public disturbances such as looting and damages to buildings.

Conclusion

Post-natal care such as delivery place and personnel, and supplements and vaccines like polio 0 vaccines and vitamin A doses needs to improve within the disaster recovery phase based on the 2008-2009 Demographic and Health Survey (DHS). More training of personnel and an introduction of supply vaults could improve post-natal care and the whole health delivery system with emphasis on home deliveries since the majority of women give birth at home. The supply of supplements and vaccines could also have been affected by the political crisis that occurred during the 2008-2009 DHS survey and tropical cyclone season. In the 2003-2004 sample, Marginal Structural Models (MSMs) might not be appropriate or effective as opposite effects were observed between results from survey weight and inverse probability weights (IPWs). Therefore, MSMs should not be used when very large differences in demographics are observed and small sample sizes are used. MSMs were effectively used in the 2008-2009 sample where a large even sample size in the two periods and smaller difference were observed.

REFERENCES

1. Weisler RH, Barbee JG, Townsend MH. Mental health and recovery in the Gulf Coast after Hurricanes Katrina and Rita. Jama. 2006;296(5):585-588.
2. Melin K, Rodríguez-Díaz CE. Community pharmacy response in the aftermath of natural disasters: time-sensitive opportunity for research and evaluation. Journal of primary care & community health. 2018;9:2150132718813494.
3. Perry H. Health for the people: National community health worker programs from Afghanistan to Zimbabwe. 2020. Washington DC: USAID.
4. Reliefweb. Madagascar: Cyclone Elita - Information Bulletin n° 1. 2004. https://reliefweb.int/report/madagascar/madagascar-cyclone-elita-information-bulletin-n-1. [http://www.ifrc.org/]
5. Reliefweb. Madagascar - Cyclone Elita OCHA Situation Report No. 1. 2004. https://reliefweb.int/report/madagascar/madagascar-cyclone-elita-ocha-situation-report-no-1. [http://www.unocha.org/]
6. Shilkofski N, Agueh M, Fonseka M, Tan A, Cembrano JR. Pediatric emergency care in disaster-affected areas: A firsthand perspective after typhoons Bopha and Haiyan in the Philippines. Journal of pediatric intensive care. 2017;6(01):019-027.
7. Reliefweb. UNICEF Humanitarian Action: Madagascar Donor Update 3 Apr 2007. 2007. https://reliefweb.int/report/madagascar/unicef-humanitarian-action-madagascar-donor-update-3-apr-2007. [http://www.unicef.org/]

8. Harville E, Xiong X, Buekens P. Disasters and perinatal health: a systematic review. Obstetrical & gynecological survey. 2010;65(11):713.

9. Badakhsh R, Harville E, Banerjee B. The childbearing experience during a natural disaster. Journal of Obstetric, Gynecologic & Neonatal Nursing. 2010;39(4):489-497.

10. Coussons-Read ME. Effects of prenatal stress on pregnancy and human development: mechanisms and pathways. Obstetric medicine. 2013;6(2):52-57.

11. Joseph NT, Curtis BH, Goodman A, Simpson LL, Ganetsky M. Disaster settings: Care of pregnant patients. 2020.

12. Goodman A, Black L, Briggs S. Obstetrical care and women's health in the aftermath of disasters: the first 14 days after the 2010 Haitian earthquake. American Journal of Disaster Medicine. 2014;9(1):59-65.

13. Clare PJ, Dobbins TA, Mattick RP. Causal models adjusting for time-varying confounding—a systematic review of the literature. International Journal of Epidemiology. 2018;48(1):254-265. doi:10.1093/ije/dyy218

14. Leatherdale ST. Natural experiment methodology for research: a review of how different methods can support real-world research. International Journal of Social Research Methodology. 2018;22(1):19-35.

15. Park SY. Reducing bias in observational studies. Korean journal of anesthesiology. 2020;73(4):269.

16. Winger DG, Nason KS. Propensity-score analysis in thoracic surgery: when, why, and an introduction to how. Elsevier; 2016. p. 1484-1487.

17. DHS. The DHS Program - Who we are. https://dhsprogram.com/Who-We-Are/About-Us.cfm

18. Mariko S, Rabeza V. Enquête de Base sur la Santé de la Reproduction et la Survie des Enfants dans les zones d'intervention USAID, à Madagascar - EBSRSE 2003-2004. Calverton, Maryland, USA : INSTAT et ORC Macro. 2005.

19. Institut National de la Statistique (INSTAT) et ICF Macro. Enquête Démographique et de Santé de Madagascar 2008-2009. Antananarivo, Madagascar : INSTAT et ICF Macro. 2010.

20. ICF International. Demographic and Health Survey Sampling and Household Listing Manual. MEASURE DHS, Calverton, Maryland, U.S.A.: ICF International. 2012.

21. Heinze G, Schemper M. A solution to the problem of separation in logistic regression. Statistics in medicine. 2002;21(16):2409-2419.

22. Croft T, Marshall A, Allen C. Analyzing DHS Data. https://dhsprogram.com/data/Guide-to-DHS-Statistics/index.htm#t=Analyzing_DHS_Data.htm

23. Ko H, Hogan JW, Mayer KH. Estimating causal treatment effects from longitudinal HIV natural history studies using marginal structural models. Biometrics. 2003;59(1):152-162.

24. Crowson CS, Schenck LA, Green AB, Atkinson EJ, Therneau TM. The Basics of Propensity Scoring and Marginal Structural Models 2013;

25. Cole SR, Hernán MA. Constructing inverse probability weights for marginal structural models. American journal of epidemiology. 2008;168(6):656-664.

26. Williamson T, Ravani P. Marginal structural models in clinical research: when and how to use them? Nephrology Dialysis Transplantation. 2017;32(suppl_2):ii84-ii90.

27. Andersson HC, Narumanchi T, Cunningham A, Bowdish B, Thoene J. Genetic/metabolic health care delivery during and after hurricanes Katrina and Rita. Molecular genetics and metabolism. 2006;88(1):3-6.

28. Institute of Medicine. Committee on Post-Disaster Recovery of a Community's Public Health M, Services S. Healthy, resilient, and sustainable communities after disasters: strategies, opportunities, and planning for recovery. National Academies Press; 2015.

29. Reliefweb. CWS Emergency Appeal: Madagascar Cyclone Relief. 2004. https://reliefweb.int/report/madagascar/cws-emergency-appeal-madagascar-cyclone-relief [https://cwsglobal.org/]

30. Callaghan WM, Rasmussen SA, Jamieson DJ, et al. Health concerns of women and infants in times of natural disasters: lessons learned from Hurricane Katrina. Maternal and child health journal. 2007;11(4):307-311.

31. Harville EW, Do M. Reproductive and birth outcomes in Haiti before and after the 2010 earthquake. Disaster Medicine and Public Health Preparedness. 2016;10(1):59-66.

32. Reliefweb. Madagascar: UNICEF responds to the immediate needs for children and women affected by political unrest, drought and Cyclones Eric and Fanele. 2009. https://reliefweb.int/report/madagascar/madagascar-unicef-responds-immediate-needs-children-and-women-affected-political [https://www.unicef.org/]

33. Reliefweb. Madagascar: Tropical Cyclones DREF No. MDRMG004. 2009. https://reliefweb.int/report/madagascar/madagascar-tropical-cyclones-dref-no-mdrmg004 [https://www.ifrc.org/]

34. Walraven G, Mkanje R, Roosmalen J, Van Dongen P, Dolmans W. Perinatal mortality in home births in rural Tanzania. European Journal of Obstetrics & Gynecology and Reproductive Biology. 1995;58(2):131-134.

35. Montagu D, Yamey G, Visconti A, Harding A, Yoong J. Where do poor women in developing countries give birth? A multi-country analysis of demographic and health survey data. PloS one. 2011;6(2):e17155.

36. Sánchez-Redondo MD, Cernada M, Boix H, et al. Home births: a growing phenomenon with potential risks. Anales de Pediatría (English Edition). 2020;93(4):266. e1-266. e6.

37. Oliveira JM, Allert R, East CE. Vitamin A supplementation for postpartum women. Cochrane Database of Systematic Reviews. 2016;(3)

38. Campos AP, Vilar-Compte M, Hawkins SS. Association between breastfeeding and child stunting in Mexico. Annals of global health. 2020;86(1)

APPENDIX

Appendix A

Table A1: Primary Sampling Unit (PSU) Distribution by Area of Study and Province (n=760)

Province	Capital	Other Major Urban Centers	Secondary Urban Centers	Rural
Antananarivo	84	16	28	104
Fianarantsoa	--	12	36	88
Toamasina	--	16	36	72
Mahajanga	--	16	20	48
Toliara	--	8	40	68
Antsiranana	--	12	16	40

Table A2: Primary Sampling Unit (PSU) Distrbution by Area of Study and Region (n=21835)

Region	Urban	Rural
Alaotra Mangoro	82	964
Amoron'i Mania	30	703
Analamanga	0	1983
Analanjirofo	68	977
Androy	0	750
Anosy	61	618
Antananarivo	982	0
Atsimo Andrefana	132	1218
Atsimo Atsinanana	52	861
Atsinanana	223	1023
Betsiboka	13	306
Boeny	169	580
Bongolava	24	442
Diana	213	480
Haute Matsiatra	188	1097
Ihorombe	22	304
Itasy	24	712
Melaky	12	310
Menabe	45	569
Sava	100	901
Sofia	69	1240

Vakinankaratra	203	1590
Vatovavy Fitovinany	51	1444

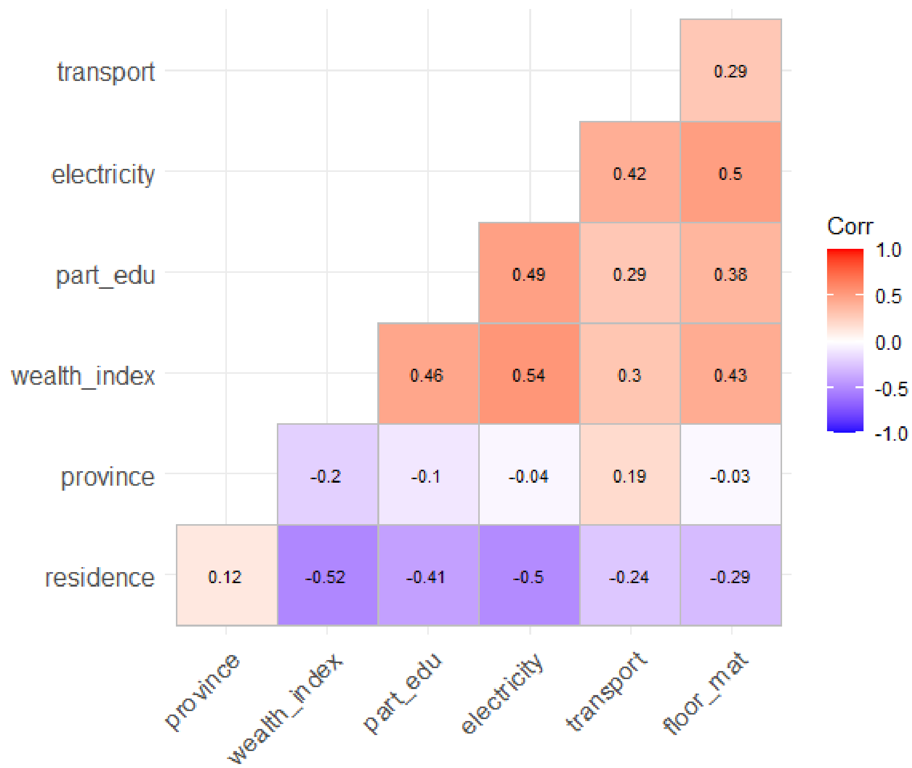

Figure A1: Correlation Matrix of Demographic Variables

Appendix B

Table B1: IPW Model Diagnostics and Covariate Selection (2003-2004 DHS)

Variables		IPW1	IPW2	IPW3	IPW4	IPW5	IPW6	IPW7	IPW8	IPW9
Type of residence	Urban Residence	REF	REF	REF	REF	REF	REF	REF	REF	REF
	Rural residence	-0.655 (0.816)	-0.287 (0.778)	-0.675 (0.728)	-0.178 (0.802)	-0.447 (0.686)	-0.431 (0.720)	-0.621 (0.620)	-0.307 (0.731)	-0.474 (0.627)
Province	Province 1	REF	REF	REF	REF	REF	--	--	--	--
	Province 2	-4.222 (1.246)	-3.946 (1.227)	-4.231 (1.244)	-3.896 (1.216)	-3.396 (0.952)	--	--	--	--
	Province 3	-1.165 (0.877)	-1.153 (0.907)	-1.220 (0.876)	-1.118 (0.928)	-1.261 (0.816)	--	--	--	--
	Province 4	-2.095 (1.552)	-1.535 (1.463)	-2.113 (1.550)	-1.575 (1.479)	-2.290 (1.398)	--	--	--	--
	Province 5	-4.169 (1.360)	-3.656 (1.257)	-4.181 (1.354)	-3.625 (1.222)	-3.979 (1.137)	--	--	--	--
	Province 6	-0.880 (1.140)	-0.596 (1.202)	-0.863 (1.142)	-0.533 (1.184)	-0.745 (1.242)	--	--	--	--
Wealth index	Low wealth index	REF	--	REF	--	--	--	REF	--	--
	Middle wealth index	-0.361 (0.574)	--	-0.402 (0.583)	--	--	--	0.553 (0.533)	--	--
	Rich wealth index	-3.498 (1.709)	--	-3.511 (1.607)	--	--	--	-2.027 (1.301)	--	--
Partner's education	No education	REF	REF	REF	REF	--	REF	REF	REF	--
	Primary education	0.307 (0.594)	-0.160 (0.535)	0.307 (0.588)	-0.154 (0.527)	--	0.125 (0.452)	0.324 (0.497)	0.107 (0.456)	--
	Secondary or higher education	0.690 (0.946)	-0.153 (0.868)	0.701 (0.988)	-0.406 (0.847)	--	-0.135 (0.891)	0.284 (0.828)	-0.318 (0.903)	--
Electricity	No electricity in household	REF	REF	--	--	--	REF	--	--	--

	Having electricity in household	-0.005 (1.155)	-0.814 (0.764)	--	--	--	-0.672 (0.762)	--	--	--
Transportation access at home	No transportation	REF	REF	REF	REF	REF	REF	REF	REF	REF
	Having transportation	1.651 (0.815)	1.480 (0.731)	1.588 (0.786)	1.287 (0.654)	0.743 (0.690)	1.684 (0.714)	1.706 (0.749)	1.561 (0.682)	1.105 (0.701)
Floor material of respondent's home	Natural floor material	REF	REF	REF	REF	REF	REF	REF	REF	REF
	Rudimentary floor material	-1.412 (1.157)	-1.034 (1.056)	-1.421 (1.164)	-1.049 (1.066)	-1.321 (0.905)	-1.601 (1.038)	-1.786 (1.044)	-1.596 (1.035)	-1.820 (0.836)
	Finished floor material	1.733 (0.927)	0.018 (0.991)	1.740 (0.928)	-0.025 (0.970)	-0.535 (0.840)	-0.465 (1.149)	0.675 (1.324)	-0.508 (1.142)	-0.815 (0.811)
IPW Weight summary statistics (Mean, Standard Deviation, Range)		7.45 (43.3)	6.67 (41.1)	23.70 (306)	6.88 (47.0)	3.40 (20.3)	2.91 (8.86)	5.63 (28.2)	2.73 (7.39)	2.47 (5.92)
		1.0 - 606	1.0 - 422	1.0 - 5350	1.0 - 574	1.0 - 303	1.02 - 100	1.0 - 354	1.02 - 60.4	1.02 - 42.6
Sum of squared weighted differences in proportions		0.478	0.353	0.294	0.186	1.026	0.369	0.165*	0.205	0.288

* Selected IPW model for analysis that minimizes demographic variability between the pre-disaster and post-disaster periods