

Unearthed Disparities: Exploring the Effects of Earthquakes on HIV Care Accessibility in Latin America

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B.S. Applied Statistics 2024



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Link to slideshow

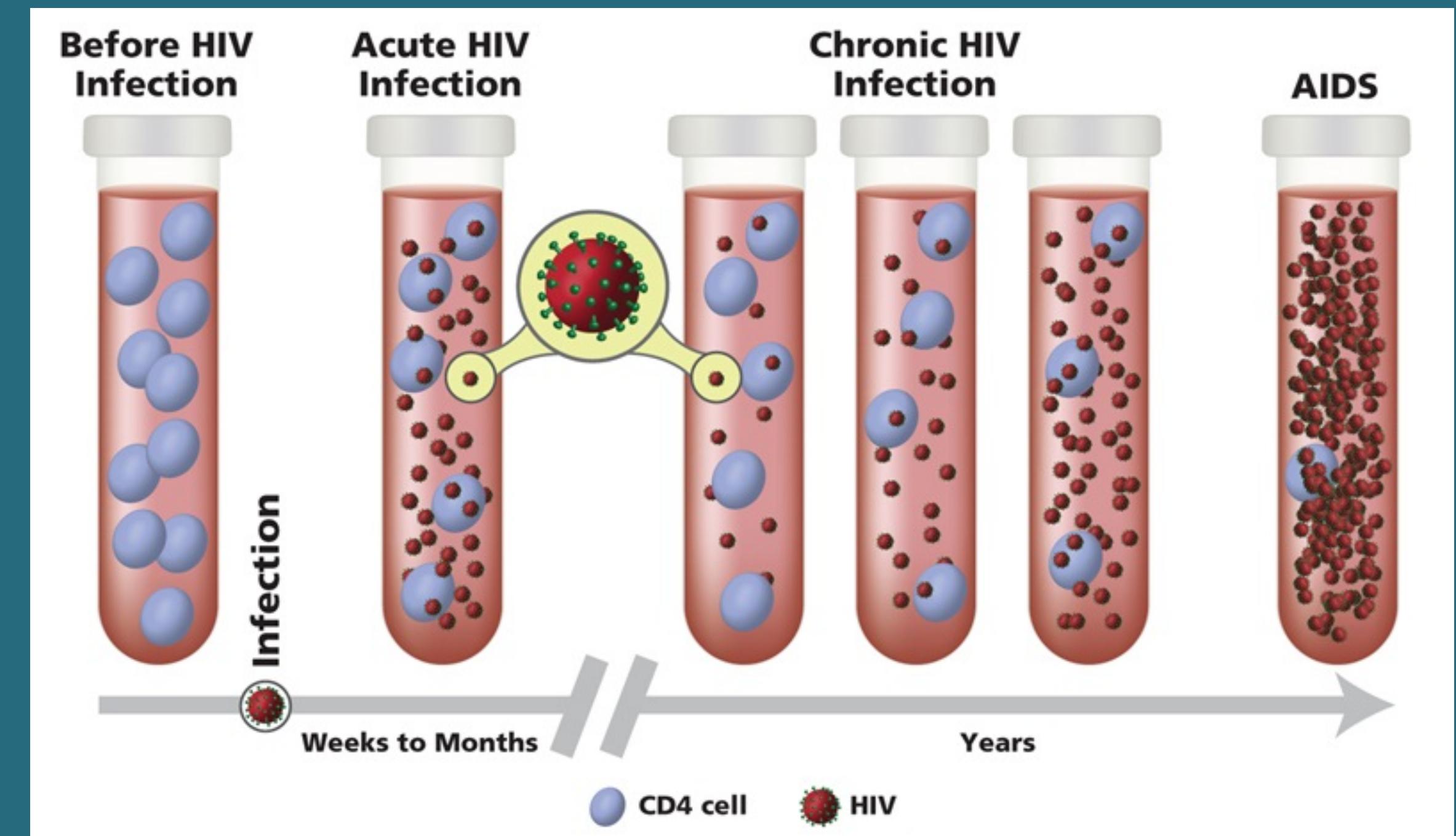
https://github.com/sarahlotspeich/unearthed_disparities



Background

Human Immunodeficiency Virus (HIV)

- Chronic healthcare ailment that affects nearly **40 million people** across the globe
- Three stages after infection:
 1. Acute HIV Infection
 2. Chronic HIV Infection
 3. Acquired Immunodeficiency Syndrome (AIDS)



Source: HIVInfo.gov

Continuity of Care (ART)

- Treatments have been created to reduce symptoms and help **people living with HIV (PLWH)** to live longer, healthier lives.
- **Antiretroviral therapy (ART)** has greatly decreased mortality rates by reducing a person's HIV viral load (i.e., the number of HIV-infected cells in their body) by targeting viral enzymes and blocking viral replications.
- The goal of these treatments is ultimately **viral suppression**, which occurs when a person's HIV viral load drops below the detectable limit of standard assays.
- Once undetectable, the virus can not be spread (**undetectable = untransmittable**).



Source: DALL-E

CCASAnet

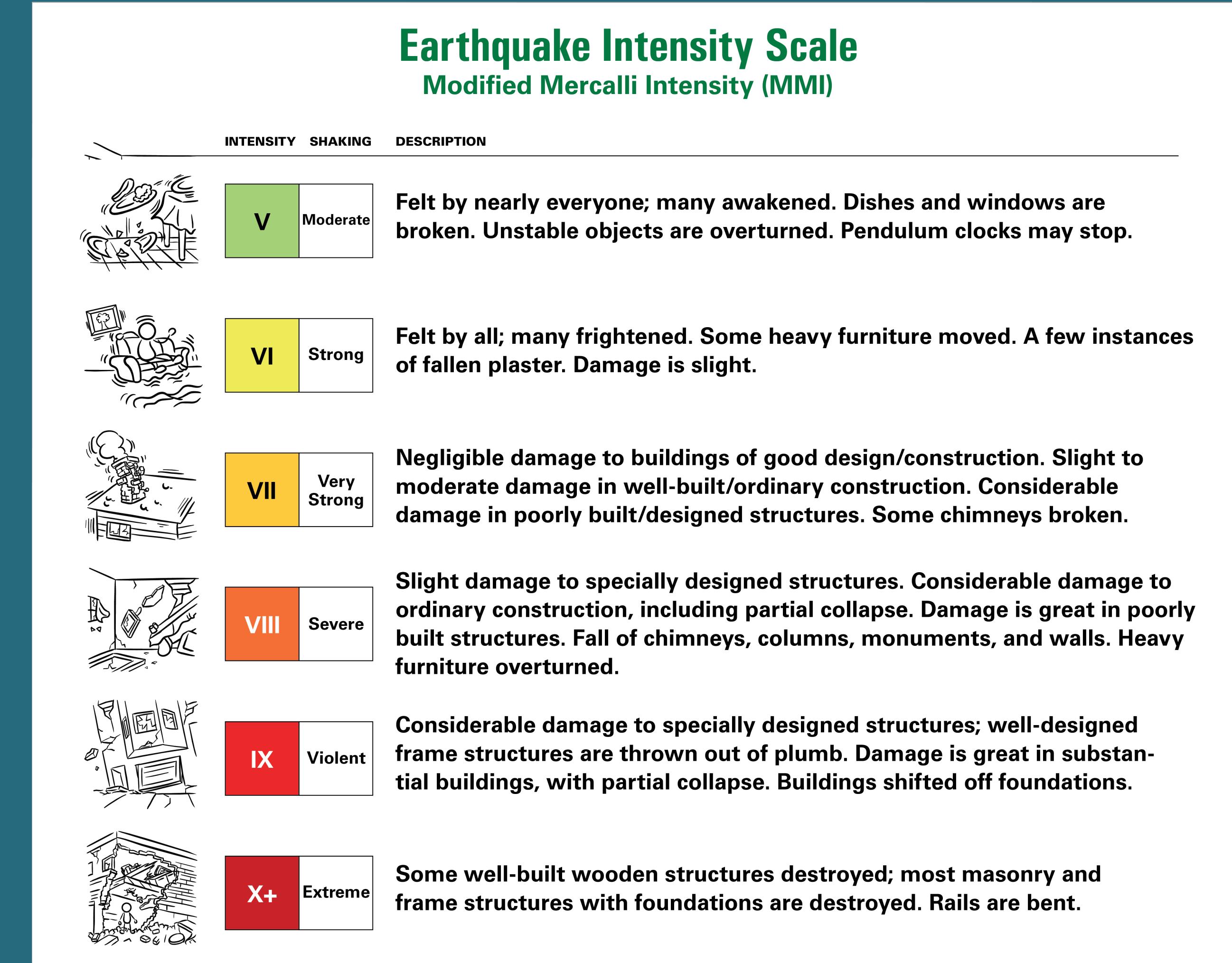
Caribbean, Central, and South America Network for HIV Epidemiology



- CCASAnet combines **site-level data** from HIV clinics across multiple countries to answer questions about HIV across the larger Latin American region.
- To achieve and maintain viral suppression, people living with HIV engage in care more frequently and generate large amounts of **routinely collected observational data** at participating clinics.
- Data collected at these clinical sites relevant for this study include the numbers of (1) **clinic visits**, (2) **CD4 measurements**, (3) **viral load labs**, and (4) **initiations of new ART regimens**.

Natural Disasters

- Natural disasters like earthquakes can **interrupt the frequency of care** of individuals near these research sites.
- In addition to the physical impacts, natural disasters tend to **intensify pre-existing social and economic disparities**.
- There have been over **700 earthquakes of moderate intensity** (Modified Mercalli Intensity [MMI] > 5) within 300 miles of a CCASAnet in the past two decades.
- This complicates the process for patients who require frequent care, making it **challenging for them to receive the comprehensive treatment** they need.



Source: U.S. Geological Survey

Objective

**To use statistical methods to quantify the impacts of earthquakes
on access to care for people living with HIV in Latin America**



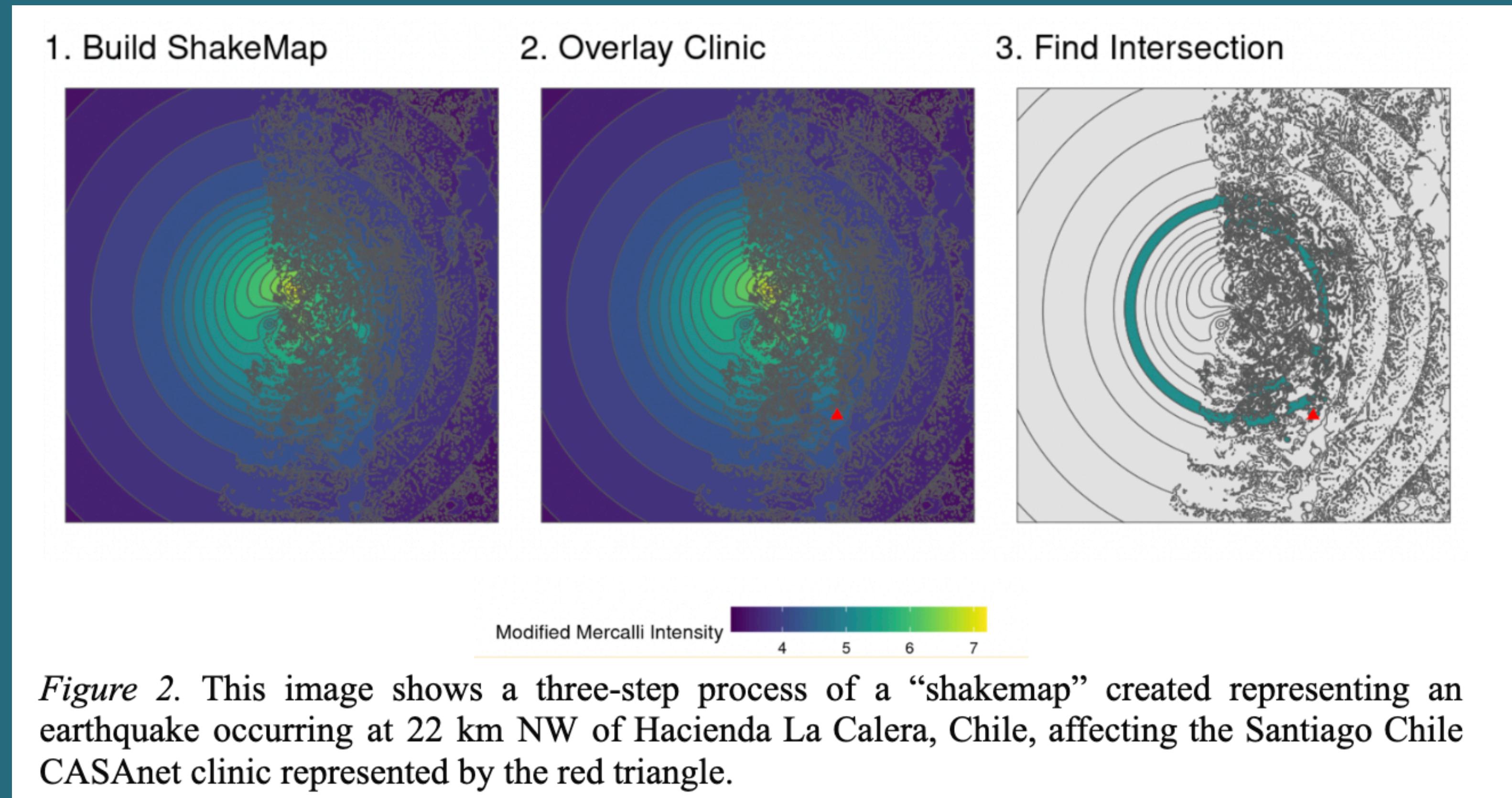
Methods

Data Collection

- Earthquake data was collected from **January 2000 to December 2023** near each CCASAnet location.
- **The U.S. Geological Survey (USGS)** works to maintain natural disaster monitoring for purposes like this on their website.
- The weekly numbers of patients in care were simulated, based on a prior CCASAnet study, **along with the numbers of visits, CD4 labs, viral load labs, and new ART regimen initiations**, for each clinic and earthquake.
- These four clinical outcomes are considered as measures of how many patients are actively engaging in care at the clinic each week, **while changes may indicate a disruption of care by the earthquake**.

Shakemaps / Point-in-Polygon

Geographic Information Systems (GIS) shapefiles for each earthquake were imported into the statistical software R and used to construct “shakemaps” that represent each earthquake’s MMI overlaid with the corresponding location of the nearby CCASAnet clinic.



Statistical Analysis

- The model for best describing whether the earthquakes disrupted patients' access to care is an **interrupted time series (ITS) model**.
- Specifically, using **Poisson regression**, the rates of visits, CD4 labs, viral load labs, and new ART initiations (per 100 patients in care) were modeled.

$$\log \{ E(Y | Week, AfterQuake, MMI) \} = \beta_0 + \beta_1 Week + \beta_2 AfterQuake \\ + \beta_3 MMI + \beta_4 Week \times AfterQuake + log(P)$$

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The severity of the earthquake on the MMI scale.

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Allows the relationship between Y and Week to be different before versus after the earthquake.

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Number of patients

Statistical Analysis

- To fit this model, the `glm()` function in R was used with `family = "Poisson"`.
- To account for potential correlation between our 4 outcomes within a clinic before/after a particular earthquake, the **Newey-West robust variance estimator** was used using the R package “`sandwich`.”
- Data obtained from CCASAnet was evaluated to determine the fitted lines before and after the earthquakes, combining all of the earthquakes and clinics.
- *Figure 3* shows the predicted amount of visits per 100 patients in care in the weeks before, during, and after each earthquake as an example.

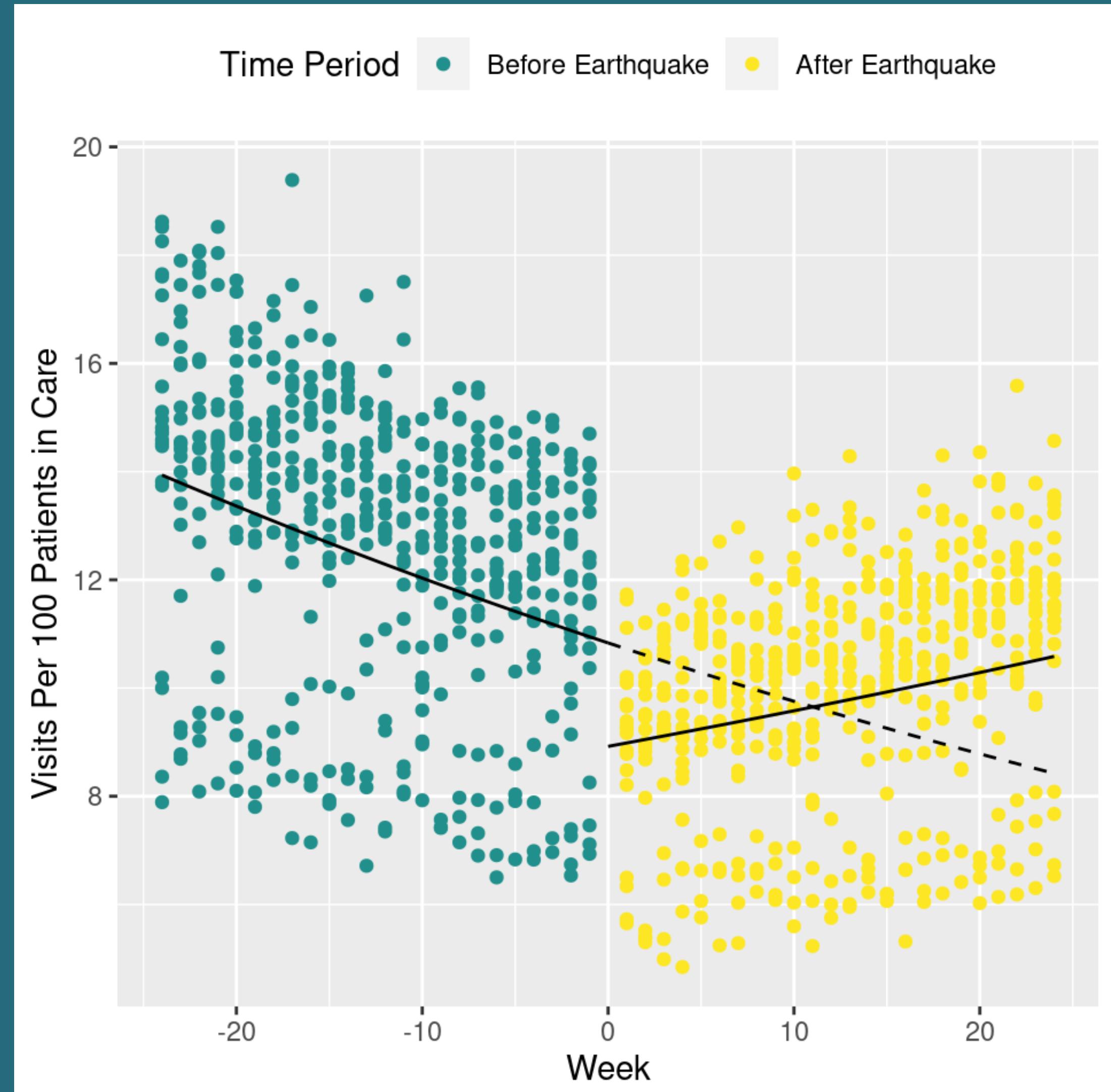


Figure 3. Fitted interrupted time series model for the weekly rate of CCASAnet clinic visits in the 6 months before/after a moderate intensity earthquake (MMI=5)

Interpreting the Models

- We are primarily interested in statistical inference about the model coefficients.
- The first quantity of interest is the **incidence rate ratio** (IRR), which tells us whether or not there was an ***immediate change in the rates of HIV care received following the earthquake***.
 - The IRR can be found by exponentiating the **coefficient β_2 on AfterQuake**
 - Construct 95% confidence interval
 - Then, we will check whether the confidence intervals for IRR contain 1, since **IRR=1** would indicate that there was no immediate change.

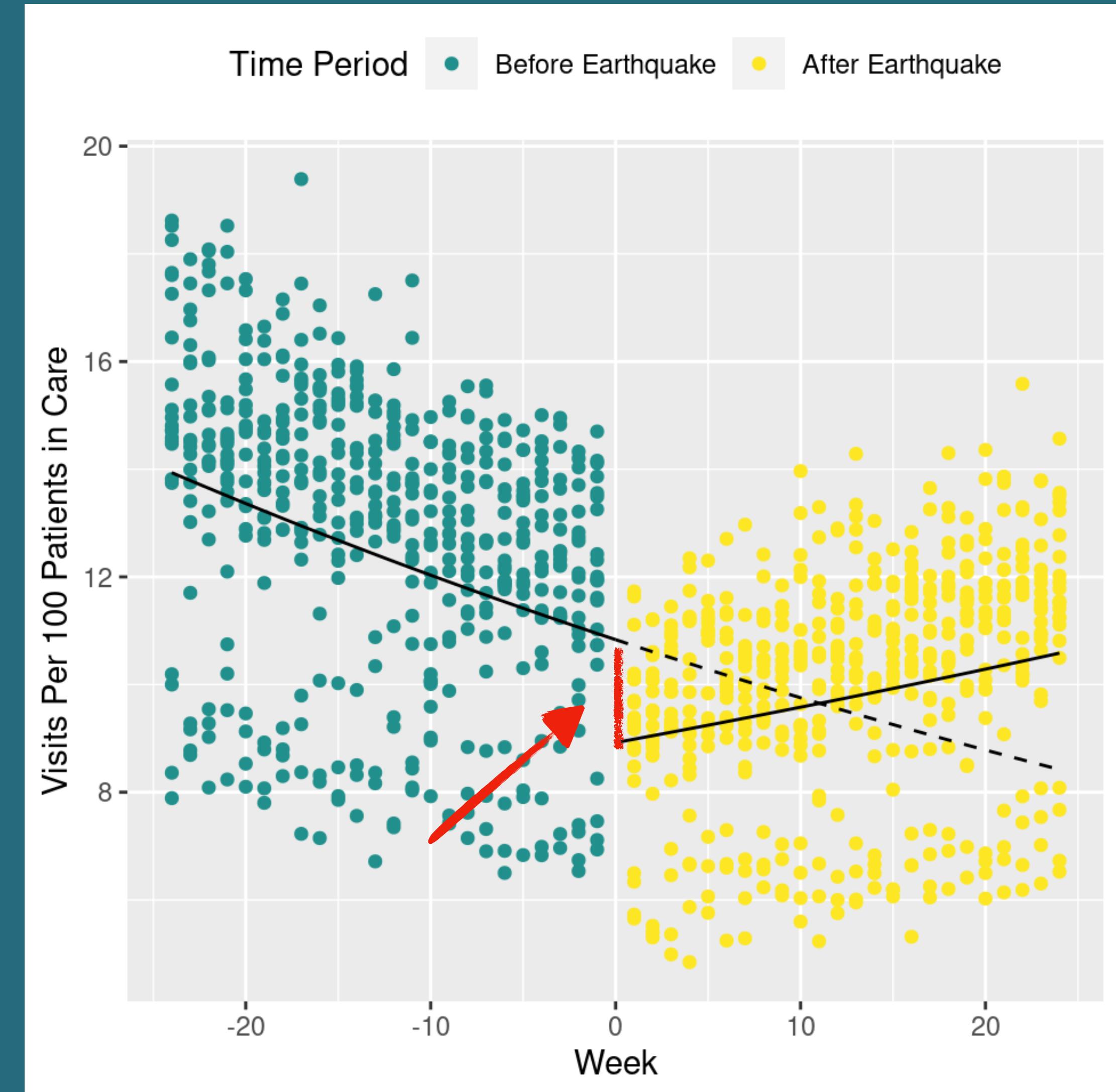


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Interpreting the Models

- The second quantity of interest is the **ratio of incidence rate ratios (IRRR)**, which tells us whether or not there was an *enduring/lasting* change in how the rates of HIV care received week-on-week following the earthquake.
 - Same process as IRR, but this time exponentiating β_4 on the interaction term **Week X AfterQuake**
 - IRR=1** would indicate that the week-on-week change in the rates of HIV care received before and after the earthquake were the same.

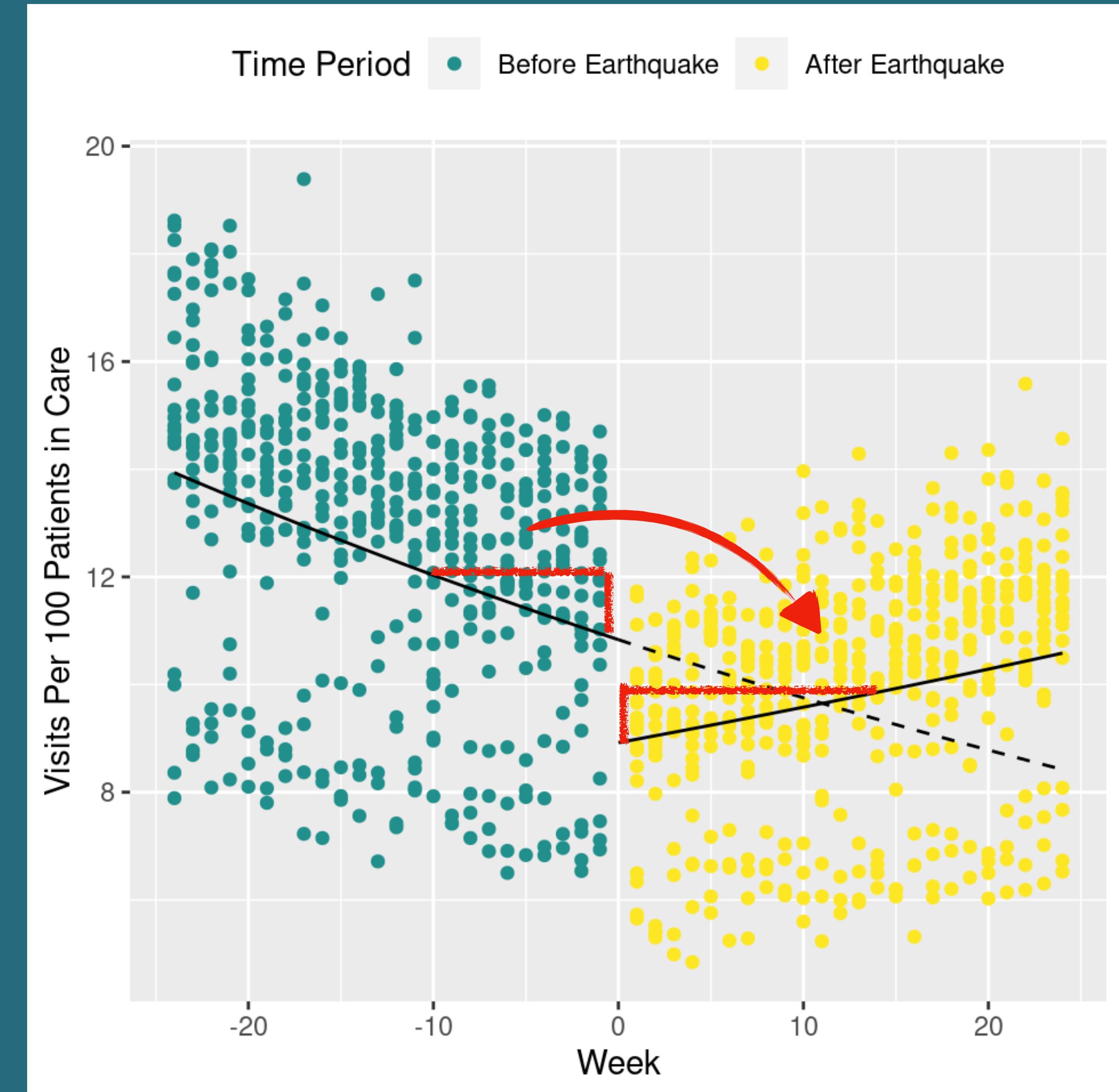


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Results

Descriptive Statistics

Clinic	Earthquakes	Weekly Median					
		Patients	Visits	CD4 Labs	Viral Load Labs	ART Initiations	
Lima, Peru	3	1593	187	67	63	5	
Santiago, Chile	5	1202	135	49	46	3	
Tegucigalpa, Honduras	3	1197	89	32	32	3	
Port-au-Prince, Haiti	10	997	128	45	44	3	
Mexico City, Mexico	1	2503	172	64	64	5	

Table 5. Weekly Medians for each of the outcomes on a clinic-specific level

Volatility in which clinics have highest numbers

Much Higher Patient Care Numbers for Mexico, City

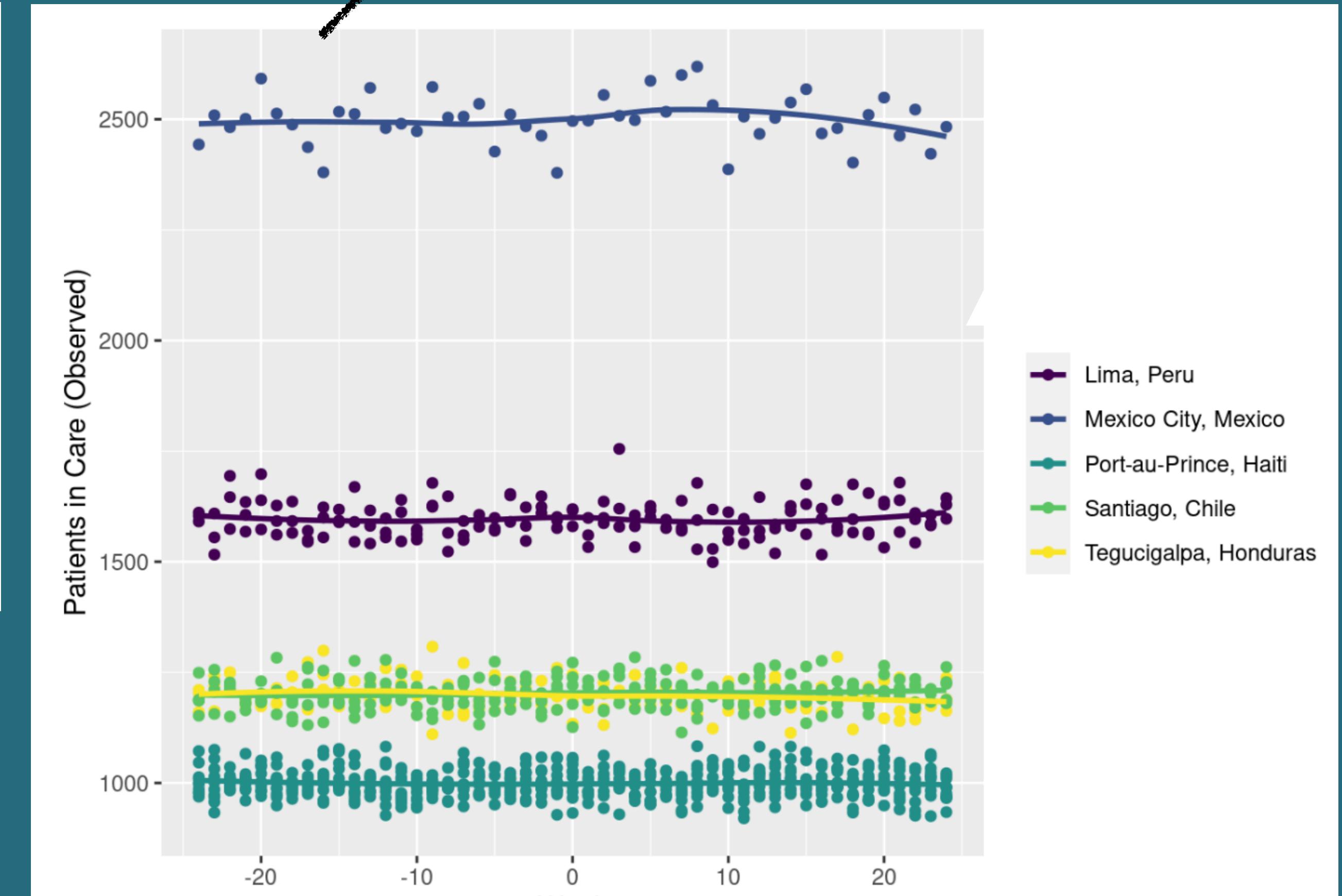
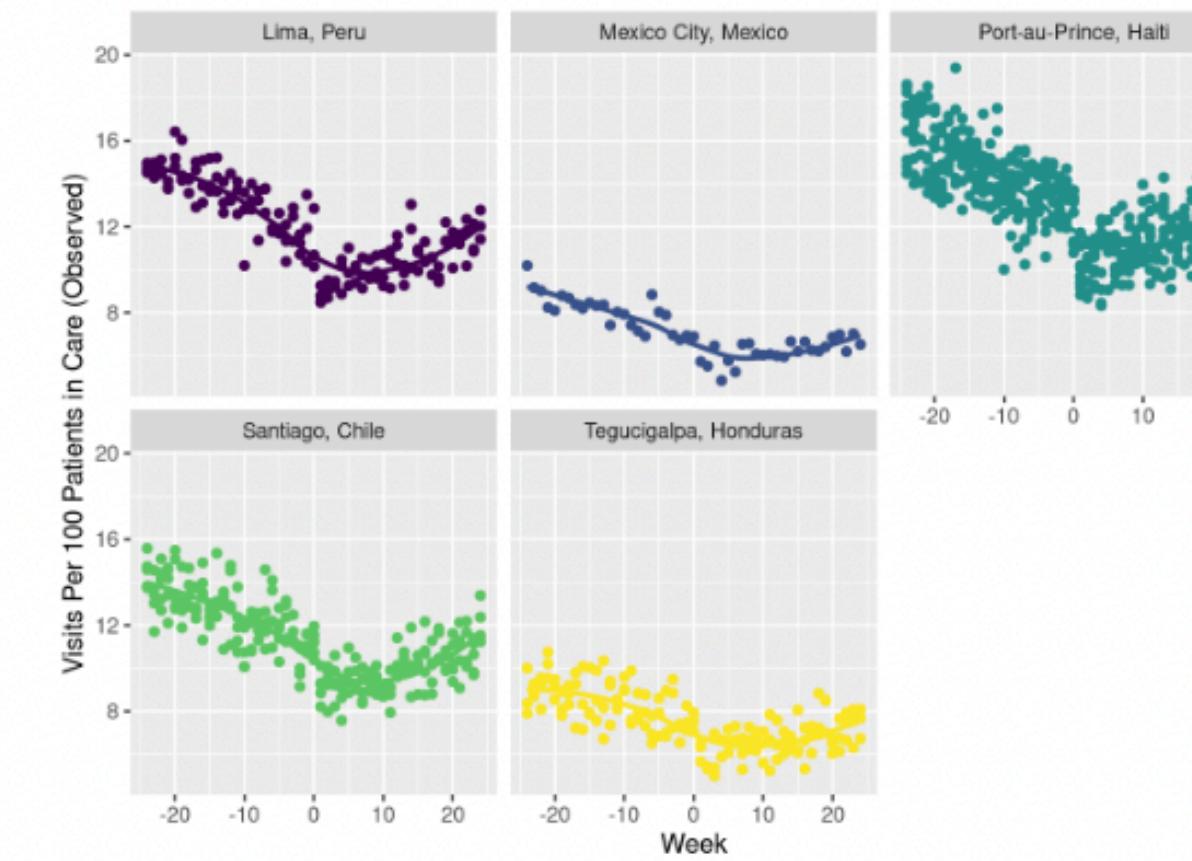


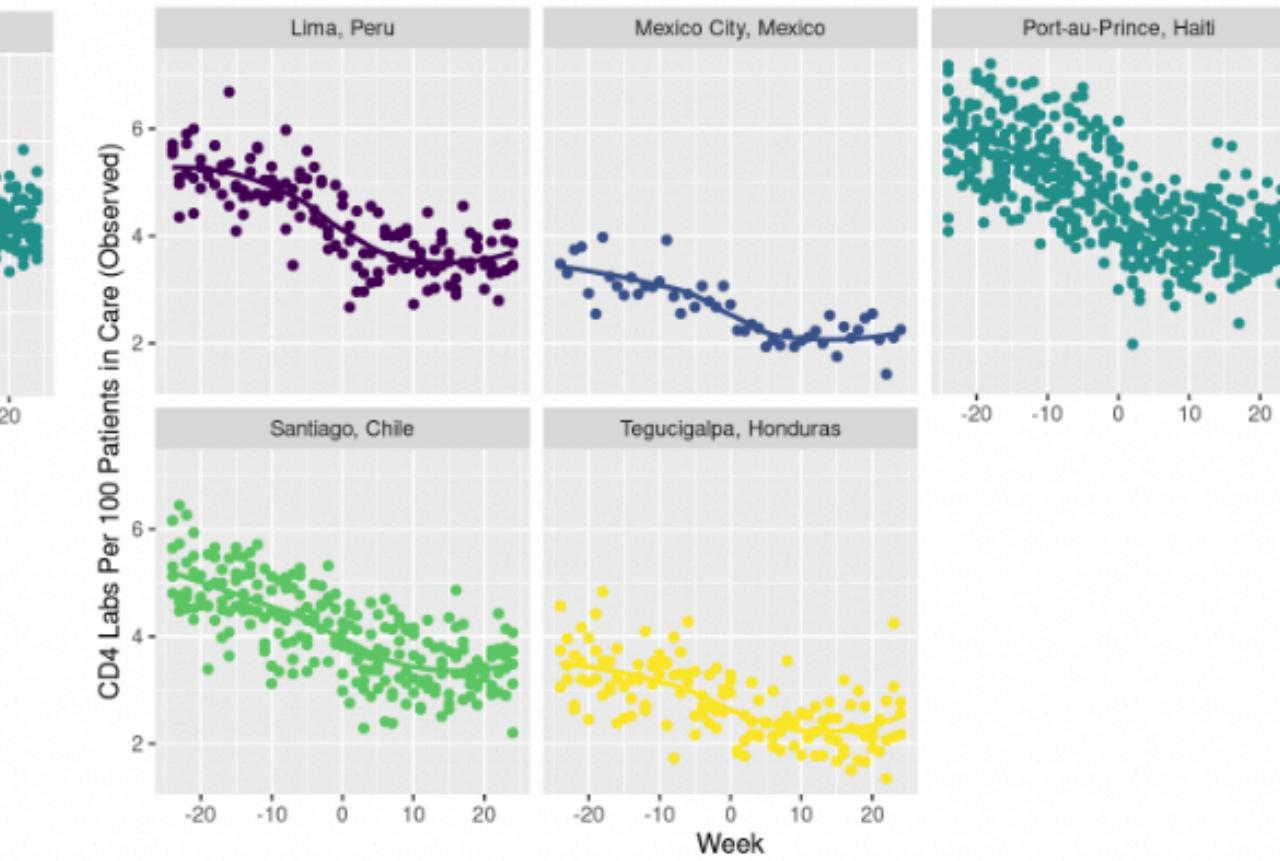
Figure 7. The number of observed patients in care for each of the five clinics

Descriptive Statistics (Clinics and Outcomes)

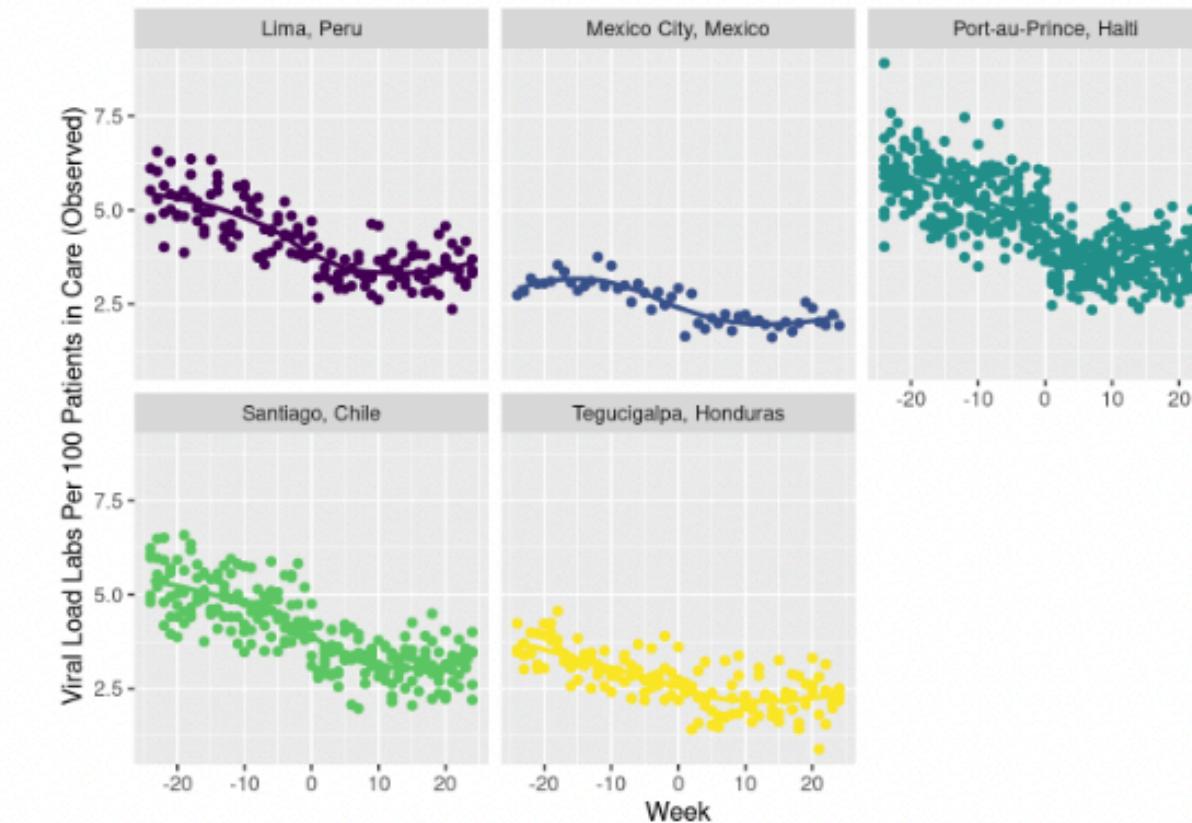
Clinic Visits
(Outcome 1)



CD4 Labs
(Outcome 2)



Viral Load Labs
(Outcome 3)



ART Initiations
(Outcome 4)

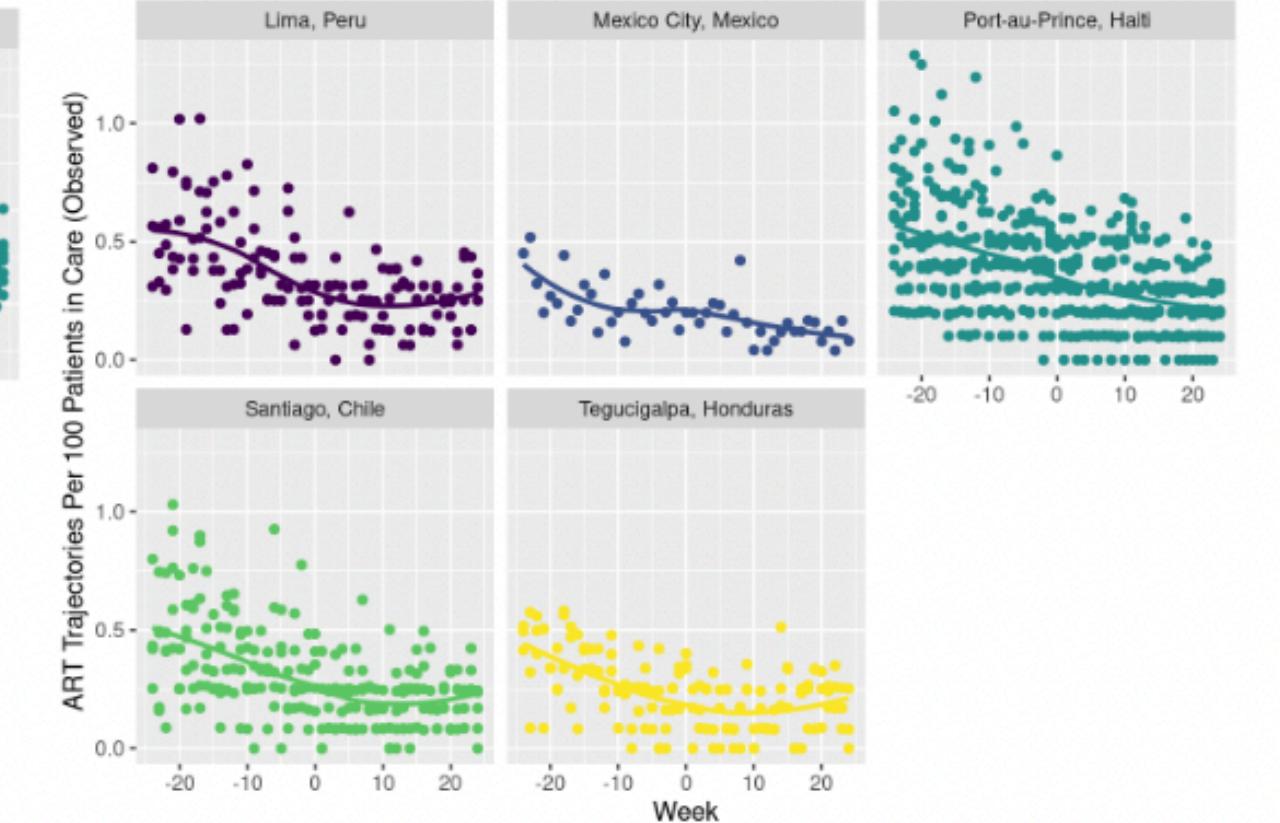
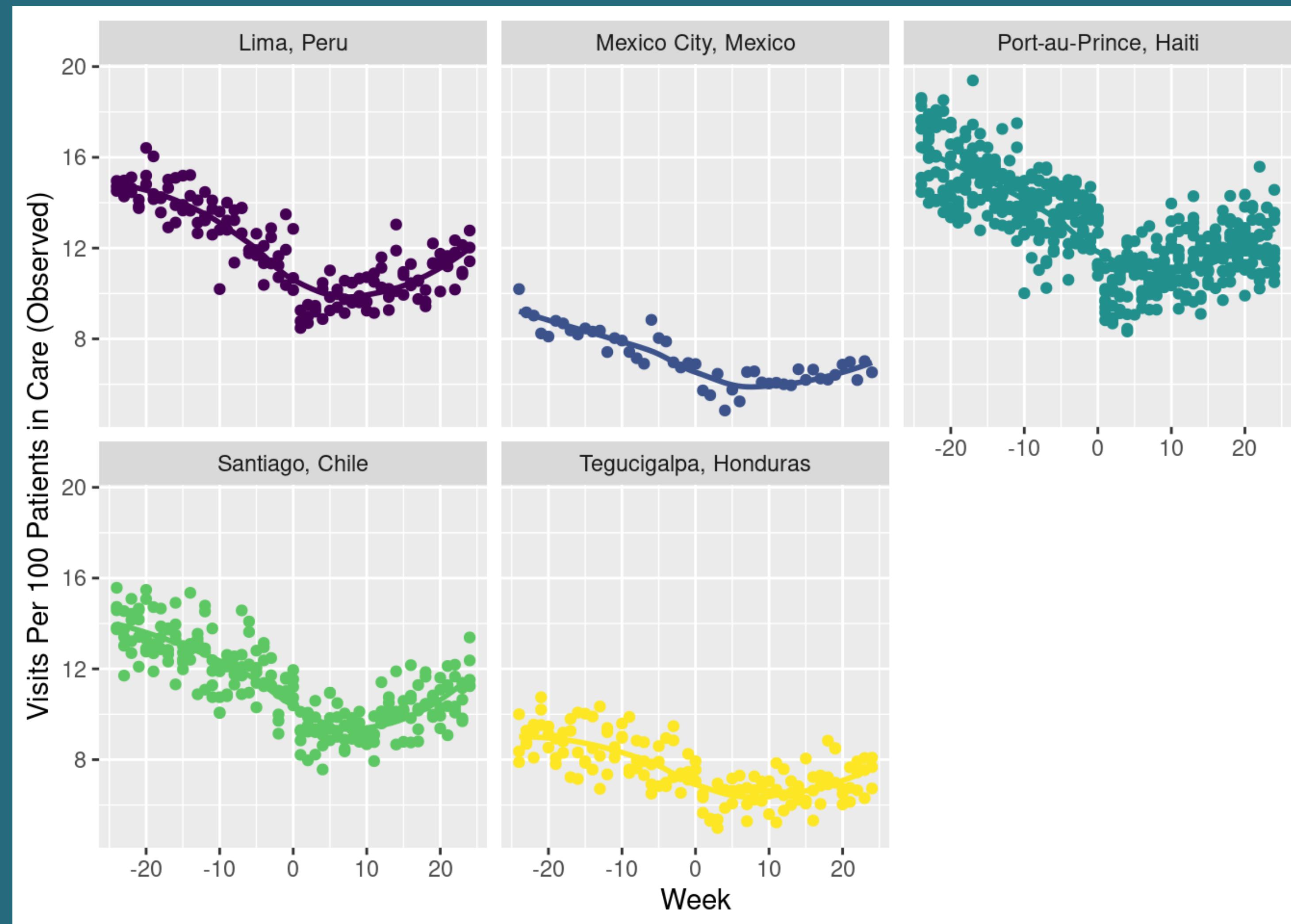


Figure 8. Scatterplots representing each clinic's observed outcomes (Visits, CD4 Labs, Viral Load Labs, ART Trajectories) per 100 patients in care

Clinic Visits (Observed)



Interruptions to Clinic Visits (Biggest)

Variable	Estimate	Confidence Interval	Robust Confidence Interval
(Intercept)	11.826	(11.588, 12.182)	(8.499, 16.445)
Week	0.990	(0.990, 0.990)	(0.980, 1)
AfterQuake (IRR)	0.824	(0.803, 0.844)	(0.733, 0.923)
MMI	0.983	(0.980, 0.990)	(0.914, 1.062)
Week × AfterQuake (IRRR)	1.018	(1.018, 1.020)	(1.010, 1.030)

Significant and immediate decline in the weekly frequency of clinical visits

Week-on-week increase in the rates of HIV care after the earthquake

Table 1. Fitted interrupted time series model for the weekly rate of CCASAnet clinic visits in the 6 months before/after earthquakes

- IRR translates to a reduction in the average number of patient visits at clinics, falling from roughly $\exp(2.47 - 0.01 \times 5) = 11.246$ per 100 individuals receiving care immediately before to $11.826 \times 0.824 = 9.258$ immediately after the earthquake.
- IRRR translates to a change in the week-on-week trend in the number of patient visits following the quake, from approximately a $(1 - 0.990) = 1\% \text{ reduction before}$ the earthquake to a $((0.990) (1.018) - 1) = .79\% \text{ increase after}$ the earthquake.

Interruptions to ART Initiations (Smallest)

Variable	Estimate	Confidence Interval	Robust Confidence Interval
(Intercept)	0.339	(0.292, 0.391)	(0.242, 0.477)
Week	0.977	(0.970, 0.980)	(0.970, 0.990)
AfterQuake (IRR)	0.819	(0.719, 0.932)	(0.698, 0.961)
MMI	0.976	(0.951, 1)	(0.905, 1.051)
Week × AfterQuake (IRRR)	1.014	(1.010, 1.020)	(1, 1.030)

Table 4. Fitted interrupted time series model for the weekly rate of CCASAnet ART Initiations in the 6 months before/after earthquakes

Still Significant

The Robust CI includes one, indicating it is possible here there is no significant change

- IRR translates to a reduction in the average number of ART trajectories, falling from roughly $\exp(-1.08 - 0.02 \times 5) = .307$ per 100 individuals before the earthquake to $.339 \times .819 = .278$ immediately following. (Much Smaller # comparing to the slide prior)
- IRRR is not significant here because the Robust CI includes IRRR = 1



Discussion

Objective

**To use statistical methods to quantify the impacts of earthquakes
on access to care for people living with HIV in Latin America**

Recap

- To look at this objective, we developed an **interrupted time series model** based on this data to evaluate our 4 outcomes: Clinic Visits, CD4 Labs, Viral Load Labs, ART Initiations.
- **IRR was significant for all 4**, least for ART Initiations
 - Remember an IRR $\neq 1$ in the confidence interval equates significance
- **IRRR was highly significant in Clinic Visits**
 - Robust CI included IRRR = 1 as the lower bound for CD4 Labs, Viral Load Labs, and ART Initiations

Takeaway

Due to frequent disruptions to care because of natural disasters, it is essential to establish and widely adopt disaster preparedness strategies to prevent interruptions in HIV care, which can lead to adverse health outcomes.

Strengths, Limitations, Reproducibility

- **Strengths:**
 - * Broad geographic scope (5 countries) over a long time period (20 years)
 - * **Applicable** to a broader audience across Latin America and other lower/middle-income countries elsewhere in the world that are affected by natural disasters.
- **Limitations:**
 - * Tried to do a **mixed-effects model, but it did not converge** with the current data. If more years of data are added to the study, it may be possible to implement a mixed-effects model in the future.
- **Reproducibility:** All data and R code used in this paper can be found fully on the GitHub here: https://github.com/sarahlotspeich/unearthed_disparities.



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- Thesis Advisor: Dr. Sarah Lotspiech
- Department of Statistical Sciences at Wake Forest University
- All of you for coming... Thank You!