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Temperature effects on prevalence of sexually transmitted infections among at-risk female sex workers in India

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Abstract: Vulnerability to climate change varies depending on the baseline climate, sensitivity to given exposure, and the presence of social, political, cultural, and institutional inequalities that influence access to essential resources of livelihood, particularly among informal labor market participants. Within the risky informal labor market, the transient nature of sex work implies that sex workers suffer disproportional losses in health, income, protection, and other aspects of general well-being as a result of the effects of climate anomalies. In this paper, I investigate the effect of temperature on the prevalence of sexually transmitted infections in a high-risk population of female sex workers in India. Using a subset of survey data that corresponds to 16,450 workers matched with temperature levels; I find noisy yet suggestive evidence that high temperatures drive infections. Given the scarcity of data and research on sex work, as well as the fact that STIs continue to contribute to the global burden of infectious diseases, this paper is one of the few that offers a new perspective to policies and interventions aimed at the prevention and control of sexually transmitted diseases, while also emphasizing the need for additional research into the interaction between climate and STIs.

1. Introduction

The United Nations has described climate change as the "largest, most pervasive threat to the natural environment and human rights of our time". A substantial body of literature demonstrates how climate impacts endanger water availability and supply, food security, and present risks to health and human security. Unfortunately, existing inequalities lead to disproportionate impacts of climate variability, intensifying risk exposure and worsening the effects for vulnerable populations such as women, young and impoverished children, migrant communities, informal labor market participants, and people with disabilities, among others (Dell, Jones & Olken, 2014; Tiwari, Jacoby and Skoufias 2013). Statistics show that women are particularly vulnerable to the effects of climate change. According to a 2013 UNDP and GGCA study, women and children are 14 times more likely than men to die in a disaster. The role of climate change in deepening inequalities is, thus, a direct threat to public health and general welfare, especially for women.

The majority of evidence from climate change and public health literature suggests that temperature is related to the disease environment and can increase the transmission of infectious diseases among humans. The primary mechanism that has been discovered to cause this effect is water supply, sanitation infrastructure, and changes in hygiene behaviors, all of which are climate-sensitive factors. According to the findings of these studies, the relative risks of infections and other heat-related morbidities are higher in young children and the elderly populations (Green et al, 2010; Xu et al 2012).

Sexually transmitted infections (STIs), also known as sexually transmitted diseases (STDs), account for a significant portion of the global burden of infectious diseases. According to a WHO study published in 2019, there are 376 million new infections of the most common STIs worldwide each year. The greater challenge, however, is detecting these infections because the majority of STDs either do not produce any symptoms or produce symptoms that are so mild that they go unnoticed, particularly in women. When STIs go undetected or untreated, they can increase the risk of HIV infection, as well as infertility and complicated pregnancies in women. Unfortunately, due to a lack of data and the interplay of behavioral dynamics, there is insufficient empirical evidence to estimate whether the same relationship between heat and disease transmission exists for STIs as well. This paper adds to the limited literature of temperature-STD research by investigating the impact of an increase in ambient monthly temperature on the prevalence of three specific STIs, namely syphilis, gonorrhea, and chlamydia, among FSWs in four Indian states: Maharashtra, Andhra Pradesh, Telangana, and Tamil Nadu.

The remainder of this paper is organized as follows. Section 2 provides a brief discussion of relevant literature on climate change, its impact on sanitation, and the disparities in STI vulnerability that motivate the research idea. Section 3 describes the datasets that were used and summarizes key variables. Section 4 outlines the methodology that was used to answer this exploratory question. Section 5 contains a discussion of the results, while Section 6 summarizes the study's key findings and some closing remarks.

2. Literature Review

Climate change has inevitable effects on public health. For example, a large body of extensive and interdisciplinary literature on climate change provides theoretical and empirical evidence on how temperature anomalies can exacerbate the incidence of heat-induced morbidities such as dehydration or exhaustion, cardiovascular diseases, infectious disease transmission such as malaria and diarrhea, and so on (Patz et al, 2015; IPCC 2014). These effects, like any other public issue, are heterogeneous because vulnerability varies with baseline socioeconomic, political, institutional, and biological conditions, which also influence their ability to cope with changes (Balbus & Malina, 2009).

Among the vastly increasing number of empirical studies, the effects of temperature have been particularly well documented, indicating that they are primarily driven by exposure to extremely high or low temperatures. High temperatures reduce the supply of clean water, cause overcrowding, and worsen sanitation outcomes by altering hygiene practices (Baker & Anttila-Hughes, 2020; Campbell-Lendrum & Corvalán, 2007). Low and middle-income countries, which have an inadequate supply of water and sanitation infrastructure may suffer significant health consequences from even minor changes in the temperature (Levy, Smith & Carlton, 2018). Evidence from the heat-sanitation research in this regard, such as the findings from Checkley et al, 2018, which finds similar patterns of change for ambient temperature during the 1997–98 *EI Niño* episode and hospital admissions for childhood diarrhea, thus motivates this study to investigate the existence of a similar effect of high temperatures on sexual health outcomes mediated by sanitary behavior.

The market for sex and the nature of its relationship with climate change are relatively understudied because the general reluctance to discuss their risky lifestyles, the transient nature of the work, or decriminalization in some regions lead to limited availability of relevant data. This, once again, suggests a lack of evidence on STDs among sex workers and their response to changes in human behavior. Until now, very few studies have found correlations between syphilis and temperature patterns, or the impact of human perceived temperature on the risks of infections (Cheng et al., 2012; Zhang et al., 2017). Furthermore, studies have revealed that alcohol consumption and drug injection are pervasive among female sex workers, putting them at a higher risk of violence and sexually risky behaviors (Rosenblum et al, 1992). Variations in the patterns of STI transmission also allow us to further categorize the vulnerability of FSWs based on age, work behavior, and migration history.

3. Data

3.1. Female Sex Workers

In 2003, the Bill & Melinda Gates Foundation launched the Avahan Project, a nationwide initiative to combat HIV/AIDS and the prevalence of STIs among high-risk populations in India, including female sex workers, men who have sex with men (MSM), transgender groups, clients of FSWs, long-distance truck drivers (LDTDs) and others. Subsequently, two rounds of Integrated Behavioral and Biological Assessments(IBBA) were conducted, from 2005-07 to 2009-10, to measure the intervention's outcomes and make data available for future modeling.

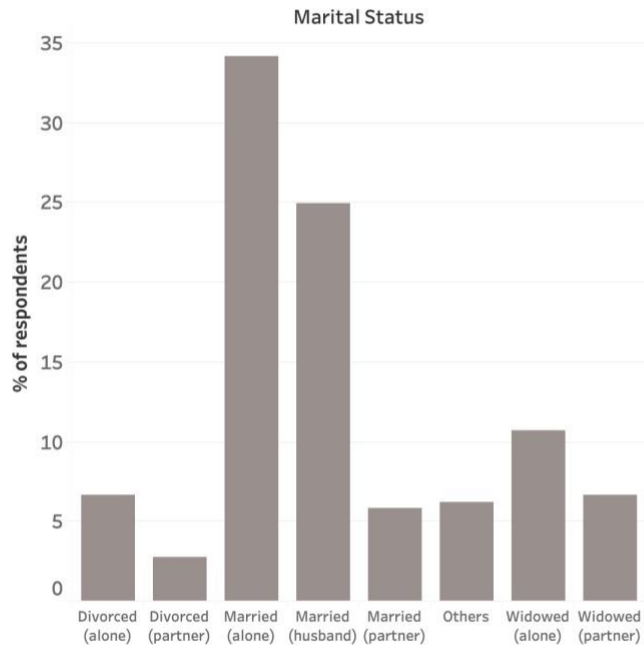
The use of such surveys, which measure behavioral and biological trends, provides a wealth of opportunities for the assessment and development of policies and programs aimed at representative high-risk populations. In these interviews, the behavioral areas of inquiry include information about the respondents' occupation, sexual history, migration patterns, perception of the risk of HIV/AIDS, participation in local communities, and intervention groups. After completing this section of the interview, a respondent's blood samples are sent to the IBBA central laboratory for analysis of various biological indicators, with their prior consent. For this research, I restrict the sample to 16,450 FSWs from a total of 19 districts in 4 states - Andhra Pradesh, Maharashtra, Telangana, and Tamil Nadu during both rounds. The definition of FSWs varies by state/district to align with the Avahan project to include brothel-based workers, non-brothel-based workers, and service bar-based workers.

The average age of respondents at the time of the surveys is 30; the youngest being 18 and the oldest being 60. The earliest age of entry into sex work, on the other hand, is 10, indicating the presence of minor entrants. More than half of the sample reported being unable to read/write or do both, and approximately 35% are married women who live alone, away from their husband/partner/families.

Table 1 & Figure 1: Female Sex Worker Summary Statistics

Variable	Mean	Min	Max
Current Age	30.812	18	60
Age at entry	24.926	10	55

Literacy	Freq.	Percent	Cum.
Can read and write	2580	15.69	15.69
Can read only	3495	21.25	36.94
Illiterate	10372	63.06	100.00
Total	16447	100.00	



STI prevalence is defined as testing positive for any one or more of the following: reactive syphilis serology [rapid plasma reagin (RPR)], Neisseria gonorrhoeae NAT and Chlamydia trachomatis NAT. Figure 1 shows that STI prevalence among FSWs varies by district within the four neighboring states. Within this subset of the population, the Yavatmal district of Maharashtra had the highest STI prevalence, with a 37 percent positivity rate. Syphilis was the most common of the three STIs, with a 9.35 percent positivity rate, compared to 2.55 percent and 4.41 percent for gonorrhea and chlamydia, respectively.

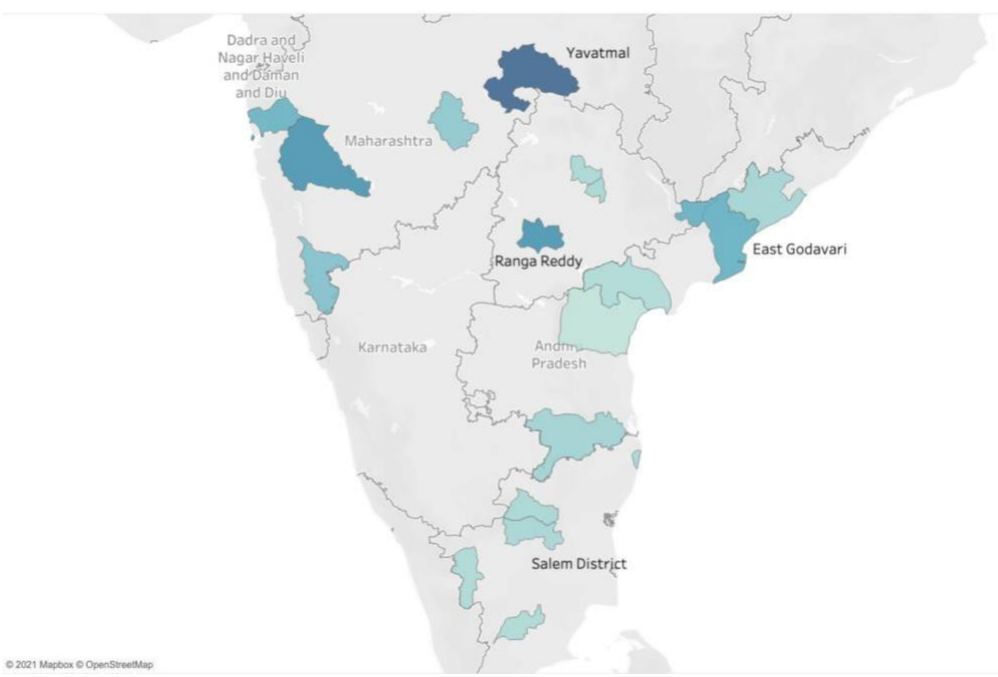
Table 2: Baseline STI prevalence

Syphilis – 1 = Positive, 0 = Negative	**Freq.**	**Percent**	**Cum.**
0	14912	90.65	90.65
1	1538	9.35	100.00
Total	16450	100.00	

Gonorrhea – 1 = Positive, 0 = Negative	**Freq.**	**Percent**	**Cum.**
0	16030	97.45	97.45
1	420	2.55	100.00
Total	16450	100.00	

Chlamydia – 1 = Positive, 0 = Negative	**Freq.**	**Percent**	**Cum.**
0	15725	95.59	95.59
1	725	4.41	100.00
Total	16450	100.00	

Figure 2: Cross-district prevalence of STIs among FSWs



3.2 Climate

I use climate data from the European Centre for Medium-Range Weather Forecasting (ECMWF) ERA5-Land reanalysis dataset, which provides hourly data on a wide range of variables such as wind speed and evaporation, as well as temperature and precipitation. I specifically use the temperature of the air at 2 meters above the surface of land, sea, or inland waters. The temperature at 2m is calculated by interpolating between the lowest model level and the Earth's surface while taking atmospheric conditions into account.

I then obtain the average temperature of the day measured at various latitudes and longitudes within a specific district in order to match these measurements with the survey results based on the date and location of the interview between 2005 and 2010. One of the main advantages of using reanalysis data is that it goes several decades back in time, providing an accurate description of the climate of the past.

4. Methodology

My identification strategy for this relatively new line of research takes advantage of plausibly random variations in monthly temperature at the district level to estimate the spatial and temporal correlation between recent temperature and STI prevalence. To begin with, I use a simple Linear Probability Model, with the results of the three serology tests serving as the dependent variable in separate regressions. The main independent variable in the first set of regressions is the average temperature of the month preceding the date of the interview, and the model includes fixed effects for the month, year, and district of the interview.

$$\text{Model 1 - } Sh_i = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 T_{1\text{-}30rdmy} + \boldsymbol{\theta}_m + \boldsymbol{\gamma}_y + \boldsymbol{\phi}_d + \boldsymbol{\varepsilon}_d$$

The IBBA dataset collects information on several demographic characteristics of respondents and their work behavior, such as work location, area of client solicitation, frequency of clients, condom and injection practices, and so on. I include an additional vector of fixed effects that control for these factors in the second set of regression equations for the three sexual health outcomes. The inclusion of these variables is intended to reduce the noise in the standard errors of the simple LPM used in model 1.

$$\text{Model 2 - } Sh_i = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 T_{1\text{-}30rdmy} + X_i + \boldsymbol{\theta}_m + \boldsymbol{\gamma}_y + \boldsymbol{\phi}_d + \boldsymbol{\varepsilon}_d$$

where X_i is a vector of fixed effects for demographics and sex-work behavior

For the third model, I relax the assumption that temperature effects are linear and consider using a flexible statistical model that allows testing for non-linearities. I do this by converting the temperature variable into discrete bins and regress the outcome variables on dummy variables that represent each temperature bin. Since the average monthly temperature in the given districts during both rounds of the survey is approximately 27°C, I drop the dummy variable that measures whether the temperature was between 27°C and 27.9°C in the month preceding the date of the interview. I then run the same regression as in model 2 to determine the marginal changes in STI prevalence in response to every 1° increase in temperature.

$$\text{Model 3 - } Sh_i = \boldsymbol{\alpha} + \boldsymbol{\beta} \sum_{i=20}^{\infty} T^{[x,\, x+0.9)}{}_{t\text{-}30} + X_i + \boldsymbol{\theta}_m + \boldsymbol{\gamma}_y + \boldsymbol{\phi}_d + \boldsymbol{\varepsilon}_d$$

where $T^{[x,\, x+0.9)}{}_{t\text{-}30} = 1[T_{t\text{-}30} \in [x, x+0.9)$

In other words, each temperature bin records a 1 if the average temperature for the month preceding the date of interview falls within the specific bin range(e.g., 28°C – 28.9°C) and a 0 otherwise.

5. Results

I begin by discussing the results of Model 1 in table 3, which is a simple LPM with space and time fixed effects. According to this estimation, the coefficients on all three infections are weak in magnitude and do not have statistical significance at the 10% level. We also see that the coefficient on syphilis is lower in magnitude as compared to the other two infections.

Table 3: Linear Probability Model with month, year and district fixed effects

	(1)	(2)	(3)
	Syphilis	Gonorrhea	Chlamydia
Average temperature over last 30 days	0.00145	0.000694	0.00467
	(0.00650)	(0.00260)	(0.00303)
Constant	0.0472	0.00306	-0.0851
	(0.177)	(0.0705)	(0.0822)
Month FE	YES	YES	YES
Year FE	YES	YES	YES
District FE	YES	YES	YES
Observations	15482	15482	15482
Adj R-squared	0.0338	0.0207	0.0208
Dependent-variable mean	0.0935	0.0255	0.0440

Clustered standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Because the coefficients in this set of estimations have highly noisy standard errors, model 2 attempts to reduce the noise by including additional controls for demographic factors such as age and literacy, as well as behavioral factors such as alcohol consumption, work location, and so on. Table 4 shows the estimates for this model, which show similar results for this relationship. As seen in model 1, we see a positive effect on infection rates, albeit weak and insignificant. However, the most important conclusion can be drawn from these findings when we compare these coefficients to the baseline prevalence rates of the STIs. The average monthly temperature, for example, increases the positivity of gonorrhea infections by 0.32 percentage points. While this may appear to be a minor increase, comparing it to the baseline rate of 2.55 percent indicates a 12 percent increase in infections.

Table 4: Linear Probability Model with controls for demographic factors and sex work behavior in addition to month, year and district fixed effects

	(1)	(2)	(3)
	Syphilis	Gonorrhea	Chlamydia
Average temperature over last 30 days	0.00272	0.00323	0.00841
	(0.00613)	(0.00244)	(0.00615)
Constant	-0.0170	-0.0687	-0.192
	(0.168)	(0.0669)	(0.168)
Demographic FE	YES	YES	YES
Sex work FE	YES	YES	YES
Month FE	YES	YES	YES
Year FE	YES	YES	YES
District FE	YES	YES	YES
Observations	5544	5544	5544
Adj R-squared	0.0334	0.0219	0.0237
Dependent-variable mean	0.0935	0.0255	0.0440

Clustered standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Finally, I estimate the equations in model 3 to look for non-linearities in temperature effects. To begin with, we see that the infection rates for gonorrhea and chlamydia appear to increase as a result of changes in temperature to a specific range. The coefficient of infectivity rises with every 1° increase in temperature from 27°C to 27.9°C until it becomes very hot at the extreme ends of the temperature range and begins to collapse. As mentioned previously, this observation is consistent with other evidence from heat and sanitation-related research in which high temperatures worsen the sanitary environment, but human behaviors drastically change above a certain threshold.

Figure 3: Non-linear effects of average monthly temperature on gonorrhea infections

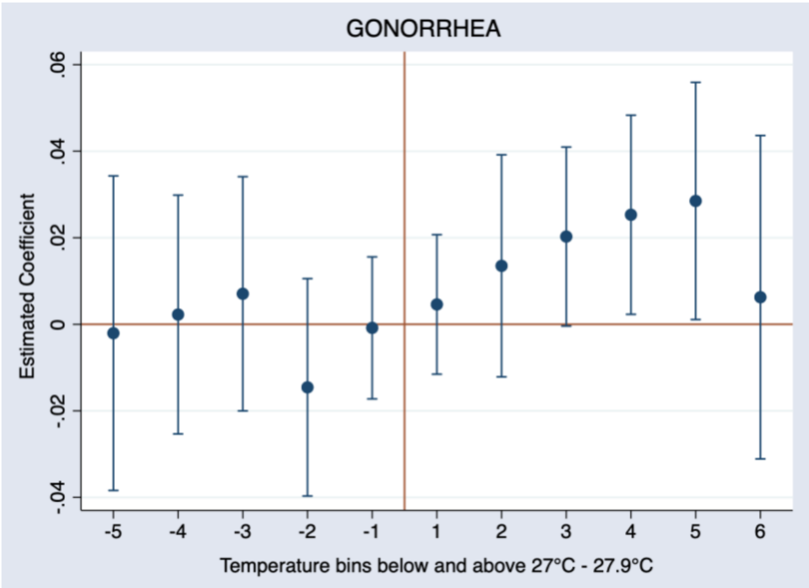


Figure 4: Non-linear effects of average monthly temperature on chlamydia infections

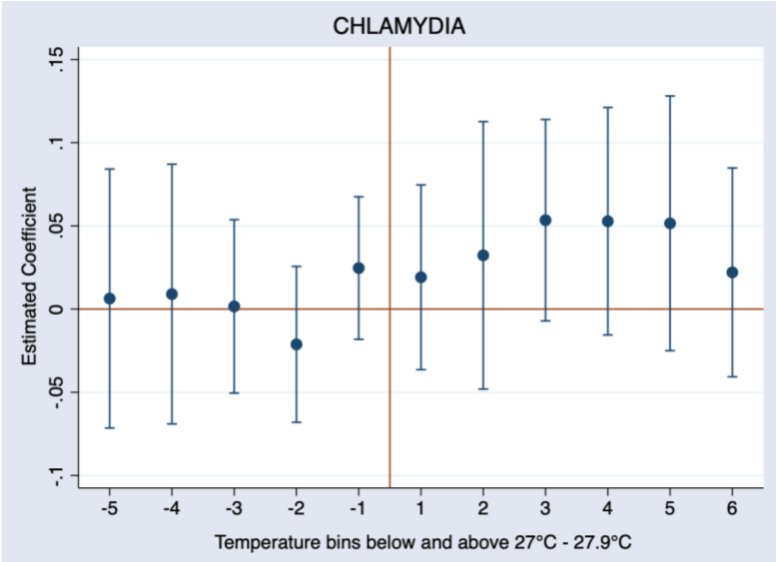
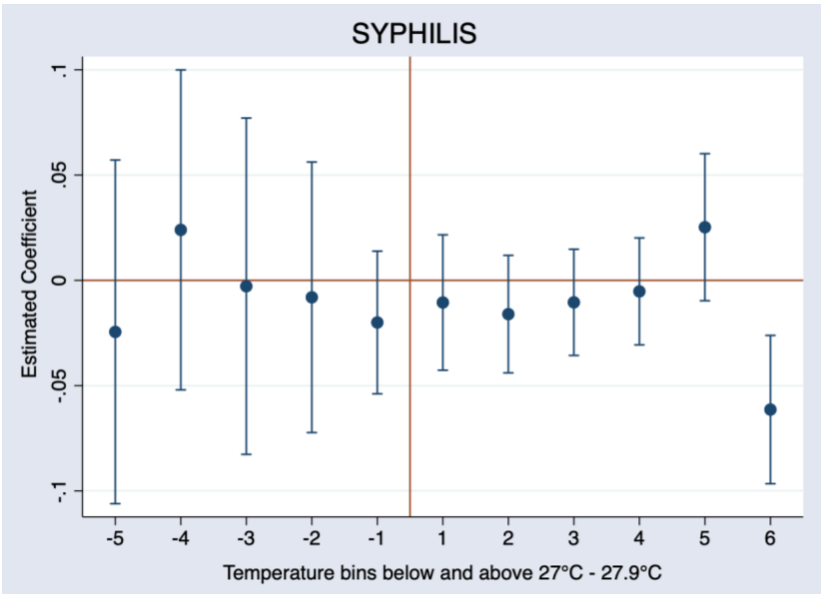


Figure 5 on the other hand, shows that the coefficients for syphilis are noisy and centered around 0. The primary reason for the disparity in the impacts on the three STIs is that syphilis infections have longer incubation periods, implying that it would be appropriate to use a measure other than average recent temperatures.

Figure 5: Non-linear effects of average monthly temperature on syphilis infections



6. Discussion

Sex work is becoming an increasingly important source of income, the activities of which are exposed to particular risks in terms of health, working conditions, exploitation, and stigmatization. Nonetheless, relevant information and research are scarce on sex work and its interactions with global issues such as climate change. This is one of the first papers that explores the relationship between temperature and sexual health outcomes for the vulnerable community of female-sex workers in high-risk areas of India. Given that temperature varies exogenously within different locations of the interviews in this survey, as well as a measure of temperature that does not capture large variations, I find noisy but suggestive evidence that high temperatures may be associated with increased spread of specific STI infections. The finding of potential non-linear effects is also consistent with evidence on behavioral factors influencing human contact and/or sexual activity. The availability of extensive socioeconomic information in a unique dataset like this also allows us to explore the heterogeneity of impacts across various sub-groups. For example, I divide the study population into multiple groups based on factors such as the age of entry, location of client solicitation or work, literacy, and so on - all of which influence their risk of acquiring STIs. I get similar results that don't show significant variation but point to potential impacts that can be determined with better models.

Furthermore, in addition to the potential increase in STI infectivity, the results for gonorrhea and chlamydia highlight the issue of coinfections. Although patients with any STD are at increased risk of coinfection with another STD, chlamydia and gonorrhea coinfections are the most common. Forty percent of women and 20% of men with chlamydial infection are co-infected with gonorrhea(Qureshi, 2021). This implies greater damages in areas with scarcity or contamination of water in areas exposed to higher temperatures.

Despite several limitations, the findings of this study suggest that climate variability can influence sexual health outcomes, particularly for high-risk groups who engage in frequent sexual activity, through mechanisms such as sanitation, living conditions, work intensity, and so on. The interaction of temperature or any other climate variable with sanitation infrastructure, particularly in densely populated tropical cities, implies that increased pressure on limited resources may result in increased disease prevalence and comorbidities, all of which have a profound impact on global health.

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