

Review Article

The Impact of El Niño on Diarrheal Disease Incidence: A Systematic Review

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To cite this article:Solomon Demissie, Bezatu Mengisitie. The Impact of El Niño on Diarrheal Disease Incidence: A Systematic Review. *Science Journal of Public Health*. Vol. 5, No. 6, 2017, pp. 446-451. doi: 10.11648/j.sjph.20170506.16**Received:** March 22, 2017; **Accepted:** April 5, 2017; **Published:** November 17, 2017

Abstract: Climate change is becoming a huge threat to the health especially for those from developing countries. Diarrhea is one of the major diseases linked with changing climate. Global climate change is expected to increase the risk of diarrheal diseases, a leading cause of childhood mortality. El Niño Southern Oscillation (ENSO) is a climate event that originates in the Pacific Ocean but has wide-ranging consequences for weather around the world, and is especially associated with droughts and floods. An El Niño occurs approximately every 3 to 7 years when warm equatorial water shifts from Western to Eastern Pacific ocean. However, there is uncertainty about the impact of climate change/ESNO on the transmission of diarrheal pathogens and diarrhea disease. The aim of this systematic review is to examine the impact of El Niño on diarrheal disease incidence in children and adults. An extensive literature review was conducted in January 2017 using electronic databases Google Scholar, PubMed, and Directory of Open Access Journals (DOAJ). The review was limited to studies reporting the impacts of El Niño on diarrheal diseases or studying associations between climate change associated with El Niño and diarrheal diseases outcomes. Over 2600 scholarly papers and potential published articles identified in the initial electronic search, of which 30 fulfilled the inclusion criteria. Evidence for an association between disease risk and ENSO is more robust when analyses use a long time-series that incorporate more than one event and when there is an appropriate geographical aggregation of data. On the basis of the evidence available, this review primarily draws upon observational studies. The result of this systematic review confirmed that most of the studies noted a significant association between diarrheal disease and El Niño. However, research on the impact of El Niño/climate change on diarrhoeal disease is limited. Longitudinal studies over extended periods of time that investigate the link between El Niño/climate change and diarrheal disease are needed. There is a need for studies to be expanded to include more countries in the region and to include other environmental, social and economic factors that might affect the incidence of diarrheal disease.

Keywords: Climate Change, El Niño, Diarrhea, Systematic Review

1. Introduction

There is growing concern that severe weather changes resulting from El Niño episodes and global climate change directly affect human health. El Niño Southern Oscillation (ENSO) describes natural variations in the global climate system and involves changes in sea temperature and atmospheric pressure across the Pacific basin. ‘Southern

Oscillation’ refers to above-average atmospheric pressures on the Indian Ocean associated with low-average pressures in the Pacific and vice versa. ‘El Niño’ episodes refer to a phase of abnormally warm Pacific Ocean surface temperatures. ENSO is a climate event that originates in the Pacific Ocean but has wide-ranging consequences for weather around the world, and is especially associated with droughts and floods. El Niño occurs approximately every 3 to 7 years when warm

equatorial water shifts from Western to the Eastern Pacific Ocean [2]. The El Niño phenomenon affects rainfall patterns and temperatures in many parts of the globe, most intensely in the tropics with significant impacts on human health [24]. Both temperature and rainfall have the potential to affect the transmission of waterborne diarrheal pathogens. Higher temperatures may increase pathogen replication and survival rates; rainfall pulses can flush fecal material into waterways, and droughts may concentrate microorganisms in water sources [4]. El Niño is currently affecting the health of millions of vulnerable people in the Horn of Africa, southern and eastern Africa, South Pacific, Central America and South Asia [24].

Climate change is predicted to have a strong influence on human health with the most vulnerable communities being those living in poverty and having the lowest capacity to adapt [1]. Sub-Saharan Africa is a particularly vulnerable region as it has the highest burden of infectious disease and is projected to be the most affected by climate change. The effect of weather on disease transmission is well recognized for many infectious diseases including diarrhea [2].

Diarrhea as one of the major diseases linked with changing the climate. Global climate change is expected to increase the burden of diarrheal diseases, a leading cause of childhood morbidity and mortality. Diarrheal illnesses are among the highest disease burden in children younger than 5 years of age worldwide and are predicted to increase with climate change [4]. Diarrhea causes approximately 700,000 deaths annually in children under age 5 years, so even small proportional increases in risk can substantially increase disease burden. However, uncertainties about the impact of climate on the transmission of diarrheal pathogens have been a key limitation in quantifying the associations of climate change with health [4].

A clearer understanding of the current role of climate change in disease patterns will help to improve forecasts of potential future impacts of projected climate change and support action to reduce the burden of diarrhea [30]. Therefore, the overall aim of this systematic review is to examine the impact of El Niño on diarrheal disease incidence in children and adults and to identify gaps in knowledge to support further research efforts.

2. Methods

2.1. Search Strategy

A systematic review of published literature in English up to the end of 2016 was conducted on the impact of El Niño on diarrheal disease incidence. Published articles on Google scholar, PubMed, and Directory of Open Access Journals (DOAJ) abstracts were systematically searched using appropriate text words using El Niño AND diarrhea as a search restriction. PubMed was chosen because of its prominent use in medical and health research. DOAJ and Google Scholar databases were consulted because they included articles relevant to our inquiry that were not indexed

in PubMed. The references cited by each potentially relevant paper, review and book chapter were scrutinized in order to locate additional potential papers.

Publication of international organizations (WHO, OCHA), past review articles on health topics, and non-peer-reviewed documents relating to El Niño AND diarrhea also considered for this systematic review. Additionally, relevant websites, such as IPCC and WHO, were also searched. The final selection was based on the full text of all potentially applicable articles.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria:

- We included studies that reported primary data on the impact of El Niño on diarrhoeal disease incidence
- Papers with explicit link between El Niño/climate change as exposure and diarrheal disease outcomes
- Retrospective/prospective cohort, longitudinal panel/time-series analysis/surveillance data study designs/methods; all countries/contexts
- Studies published in English language and relevant papers were included
- No formal quality evaluation was used in papers, meeting inclusion criteria
- Papers published since 1998 to December 2016 were included

Exclusion criteria include:

- Non-English language papers
- Cross-sectional surveys
- Editorials and letters
- Papers which did not discuss El Niño as exposure and diarrheal disease as outcomes
- Papers published before 1997

2.3. Data Extraction

Data from relevant scientific papers were extracted systematically into summary tables. The required information that was extracted from all eligible papers was as follows: data on the study, study outcome, first author's last name, year of publication and country of the study, the study name, study design characteristics, study years and finding of studies. Quality assessment of the included papers was not undertaken.

2.4. Risk of Bias and Quality Assessment

El Niño is a natural phenomenon which cannot be induced experimentally; intervention studies were neither expected nor found. Most data were observational. Due to lack of data, we did not make any exclusions on the basis of study quality. Thus, formal assessment of bias was not possible for each individual study.

3. Result and Discussion

Over 2600 scholarly papers and potential published articles identified in the initial electronic search, of which 30 fulfilled

the inclusion criteria. We first read the title of the 1,658 documents and excluded 1,582 of them because of the non-relevant titles. Secondly, we read the abstracts of the remaining literature and excluded 44 of them as they did not

meet the inclusion criteria. Finally, 30 documents were included and reviewed in this study. Figure 1 summarizes the study screening and selection process.

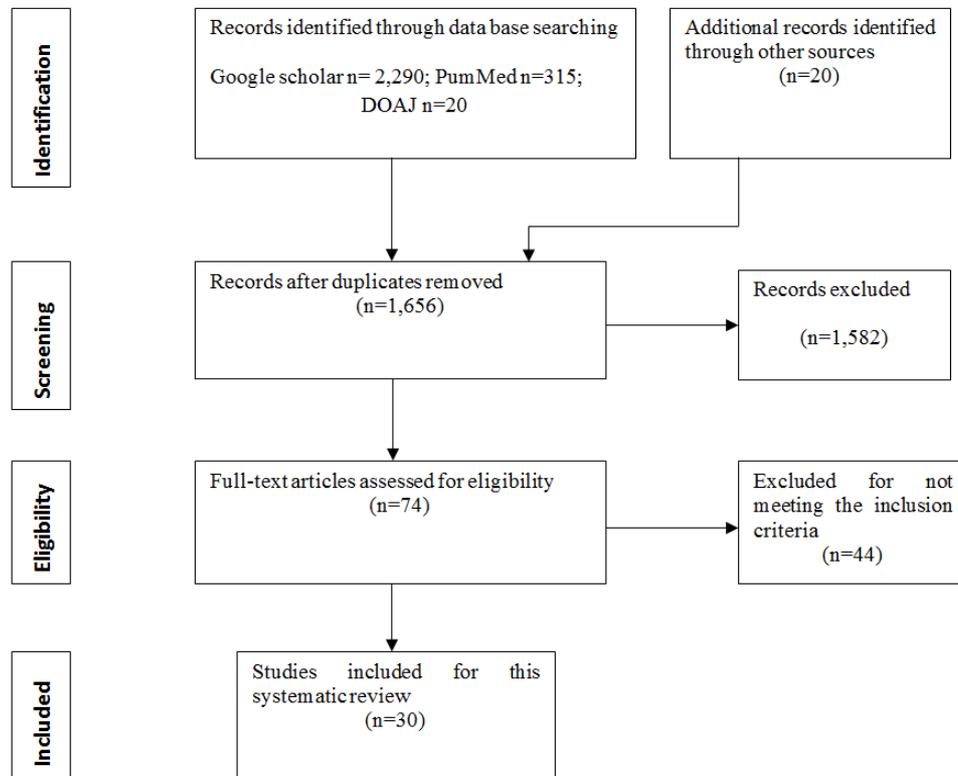


Figure 1. Flow chart of literature search strategy.

This systematic review assessed the relationship of El Niño or ENSO with diarrheal disease outcomes. Thus, we review studies conducted to determine the relationship between climate and disease risk based on El Niño. The majority 19 (63.3%) of these studies noted a significant association between diarrheal disease and El Niño. A total of nineteen studies [1-12, 16, 18, 19, 20, 23, 26-27] have linked diarrheal diseases to El Niño or climate change. Five studies were conducted in Africa, five in Latin America and Caribbean, four in America, three in Asia and one in Pacific Island and the remaining is nationwide. Most studies were descriptive in nature. Of 30 studies, 18 were observational/cohort, and/or longitudinal study with trend and time series analysis, eight were retrospective, and the remaining two were case-control studies.

Evidence for an association between disease risk and ENSO is more robust when analyses use a long time-series data that incorporate more than one event and when there is an appropriate geographical aggregation of data. The strongest evidence for an association between ENSO and disease is provided by time-series analysis with data series that include more than one event. On the basis of the evidence available, this review primarily draws upon observational studies. Observational research typically has greater risks to internal validity than randomized controlled trials, but such research is also key to providing a broad evidence base. However, in our

opinion, a true association between ENSO and disease in a given population can be confirmed only through analysis of several ENSO events with time series analysis methods.

There is evidence that El Niño events have an impact on diarrheal disease incidence. Several recent papers discuss the effects of El Niño on diarrheal diseases. A time series study conducted in Peru and the islands of Fiji estimated 8% and 3% increase in diarrhea admissions respectively, with every 1 degree Celsius increase in temperature. In Peru, daily admissions for diarrhea, increased by more than 2-fold (200%) during an El Niño event, compared with expected trends based on the previous five years [3]. During El Niño events, rates of hospitalizations of children for diarrhea increase. There is evidence of a relationship between El Niño and the timing of cholera epidemics in Peru and Bangladesh [7, 18]. Such evidence can infer high linkage of diarrheal cases occurrence with an increase in temperature [7].

In Fiji, diarrhea reports among infants increased by 2% per unit increase in rainfall and by 8% per unit decrease in rainfall. On another hand, when the temperature variable was lagged by one month, there was approximately a 3% increase in diarrhea cases per degree increase in temperature in the previous month [25]. Similar associations have been observed in many other developing country settings. Studies from India also showed a relationship between the number of cholera cases and rainfall anomalies. Extremes of rainfall also

were associated with increases in diarrhea.

Similarly, the result from other studies found a positive relationship between rising average annual temperatures

associated with the El Niño climate phenomenon and diarrheal disease reports in 18 Pacific Island countries between 1986 and 1994 [EHP 109:155–159, 2001].

Table 1. Characteristics of studies examining the relationship/impact of climate change/ El Niño on diarrheal incidence.

Title of the Article	Study outcomes	Authors	Year	Country/Region	Study Design	Study Year
Effects of the 1997–1998 El Niño Episode on Community Rates of Diarrhea <i>El Niño-associated climate variability affects community rates of diarrhea, particularly during the cooler seasons and among older children.</i>	Diarrhea	Bennett et al.	2012	Peru	Surveillance data	1995–1998
Heavy Rainfall Events and Diarrhea Incidence <i>Heavy rainfall events were associated with increased diarrhea incidence following dry periods (incidence rate ratio = 1.39, 95% confidence interval: 1.03, 1.87) and decreased diarrhea incidence following wet periods (incidence rate ratio = 0.74, 95% confidence interval: 0.59, 0.92).</i>	Diarrhea	Carlton et al.	2013	Ecuador	Surveillance data	2004–2007
Regional-scale climate-variability synchrony of cholera epidemics in West Africa <i>Results of this study suggest that large and regional scale climate variability influence both the temporal dynamics and the spatial synchrony of cholera epidemics in human populations</i>	Cholera	Guillaume et al.	2007	West African countries: Côte d'Ivoire, Ghana, Togo, Benin and Nigeria	Longitudinal cohort study	1975–1996
ENSO and cholera: A nonstationary link related to climate change? <i>There is a significant association and this climate phenomenon accounts for over 70% of disease variance.</i>	Cholera	Rodo' et al.	2002	Bangladesh	A time-series analysis	1980–2001
Environmental temperature, Cholera, and Acute Diarrhea in Adults in Lima, Peru <i>During 1991–1996, an increased number of visits to the hospital due to acute diarrhea in the warmer months was observed.</i>	Cholera and Diarrhea	Lama JR et al.	2004	Peru	A retrospective, observational and exploratory study	1991–1998
Temperature Variability and Occurrence of Diarrhea in Children under Five-Years-Old in Cape Town Metropolitan Sub-Districts <i>The mixed effect overdispersed Poisson model showed that a cluster adjusted effect of an increase of 5°C in minimum and maximum temperature results in a 40% (Incidence risk ratio IRR: 1.39, 95% CI 1.31–1.48) and 32% (IRR: 1.32, 95% CI: 1.22–1.41) increase in incident cases of diarrhea, respectively, for the two periods studied. Autocorrelation of one-week lag (Autocorrelation AC 1) indicated that a 5°C increase in minimum and maximum temperature led to 15% (IRR: 1.46, 95% CI: 1.09–1.20) and 6% (IRR: 1.06, 95% CI: 1.01–1.12) increase in diarrhea cases, respectively. In conclusion, there was an association between an increase in minimum and maximum temperature and incidence diarrhea</i>	Diarrhea	Gentile et al.	2016	S/Africa	Climatic and aggregated surveillance data	
Impact of Temperature Variability on Cholera Incidence in South Eastern Africa, 1971–2006 <i>Associations have been found between the annual increase of the air temperature in south eastern Africa and the cholera incidence increase in the same area. Thus, there is a significant exponential increase of cholera rates in humans during the study period has been confirmed.</i>	Cholera	Shlomit Paz	2009	Uganda, Kenya, Rwanda, Burundi, Tanzania, Malawi, Zambia, and Mozambique)	Cohort study	1971–2006
The Indian Ocean Dipole and Cholera Incidence in Bangladesh <i>Both negative and positive dipole events are associated with an increased incidence of cholera in Bangladesh with varying time lags.</i>	Cholera	Hashizume et al.	2011	Bangladesh	A Time serious analysis	1993–2007
Climate Change and Occurrence of Diarrheal Diseases <i>Statistically significant correlation between diarrheal cases occurrence and temperature and rainfall has been observed. However, climate variables were not the significant predictors of diarrheal occurrence.</i>	Diarrhea	Bhandari et al.	2012	Nepal	Retrospective study	1999–2008
Uncertainties Associated with Quantifying Climate Change Impacts on Human Health: A Case Study for Diarrhea <i>The associated mean projected increases in the relative risk of diarrhea in the six study regions were 8–11% (with SDs of 3–5%) by 2010–2039 and 22–29% (SDs of 9–12%) by 2070–2099. Thus, climate change has a substantial impact on the incidence of diarrhea.</i>	Diarrhea	Kolstad and Johansson	2010	Six region	Cohort Study/	
Dynamics of Cholera Outbreaks in Great Lakes Region of Africa <i>Results showed that cholera greatly increased during El Niño warm events (abnormally warm El Niño's) but decreased or remained stable between these events.</i>	Cholera	Didier et al.	2011	Burundi, Rwanda, Democratic Republic of Congo, Tanzania, Uganda, and Kenya	Cohort Study	1978–2008
Climate Change is Likely to Worsen the Public Health Threat of Diarrheal Disease in Botswana <i>There is a strong positive autocorrelation ($p < 0.001$) in the number of reported diarrhea cases at the one-month lag level. Climatic variables (rainfall, minimum temperature, and vapour pressure) predicted seasonal diarrheal with a one-month lag in variables ($p < 0.001$).</i>	Diarrhea	Kathleen et al.	2013	Botswana	A Time serious analysis	1974–2003

4. Limitations and Conclusions

4.1. Limitations

Due to its slow onset and association with other emergencies, most health effects of El Nino are indirect and therefore under-investigated, underrecognized and underreported. As it is difficult to identify El Nino as the sole exposure responsible for a given health outcome, it is likely that this search did not locate all published studies.

Reporting bias is very likely (as severe El Nino are more likely to be reported and associated with adverse health outcomes), which is one of the several reasons why quantitative meta-analysis is neither possible nor sensible in order to quantify the impact of El Nino. Important lessons on how to successfully manage El Nino to avert/minimise health effects may have been missed.

Finally, this is a systematic but not exhaustive review, which included results from peer-reviewed articles and reports published in English language only in the final analysis; there are many other valuable reports in gray literature in other languages or found under other search terms such as ENSO. However, these are extremely unlikely to change overall conclusions and interpretations and may be lower quality than the peer review published reports which were found.

4.2. Conclusions

This review provides valuable evidence which will support emergency coordinators and international assistance agencies in efforts to plan for and respond emergencies attributed to El Nino. The result of this systematic review confirmed that most of the studies noted a significant association between diarrheal disease and El Niño. Thus, there is good epidemiological evidence that El Niño is associated with an increased risk of diarrheal diseases in specific geographical areas where climate anomalies are linked with the ENSO cycle. These linkages need to be more fully appreciated by health professionals, policy-makers, and the general public.

Research and information on the impact of El Nino/climate change on diarrheal disease are limited. Longitudinal studies over extended periods of time that investigate the link between El Nino/climate change and diarrheal disease are needed. There is a need for studies to be expanded to include more countries in the region and to include other environmental, social and economic factors that might affect the incidence of disease. Advances in seasonal and El Niño phenomenon forecasting, provide the opportunity to develop long-term predictions of epidemic risk in some vulnerable areas. However, while climate change is predicted to cause an increasing global burden of diarrheal diseases, much is still to be investigated about climate factors, particularly in Africa, due to the inability to safely store health data and errors in data recording and archiving as a result of weak health infrastructure. It is important to understand climate variability as a risk factor for infectious diseases and to consider it as a foundation for

climate change awareness. Consideration of the existing evidence on the diarrheal disease risks associated with El Nino/climate change, combined with continued efforts to improve research methodologies to record these complex health effects, will support climate change policy, mitigation and adaptation measures locally, nationally and internationally.

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