Figures and figure supplements

Seasonal variation and etiologic inferences of childhood pneumonia and diarrhea mortality in India

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Figure 1. National mortality rates of (A) pneumonia and (B) diarrhea by sex, poorer/richer state, and residence type among Indian children aged 1 month to 4 years between 2005 and 2013. Each x-axis represents 2005–2013. We used a three-year moving average of the weighted proportion of deaths to calculate mortality rates (per 1000 live births). We adjusted death data to reflect 2015 data from the United Nations Population Division and Inter-agency Group for Child Mortality Estimation. Poorer states include the Empowerment Action Group-Assam states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha (Orissa before 2011), Rajasthan, Uttarakhand, and Uttar Pradesh. Richer states include all other states and union territories.

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Figure 2. National mortality rates of (A) pneumonia and (B) diarrhea by sex, poorer/richer state, and residence type among Indian children aged 5 to 14 years between 2005 and 2013. Each x-axis represents 2005–2013. We used a three-year moving average of the weighted proportion of deaths to calculate mortality rates (per 100,000 population). We adjusted death data to reflect 2015 data from the United Nations Population Division and Inter-agency Group for Child Mortality Estimation. Poorer states include the Empowerment Action Group-Assam states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha (Orissa before 2011), Rajasthan, Uttarakhand, and Uttar Pradesh. Richer states include all other states and union territories. DOI: https://doi.org/10.7554/eLife.46202.006
Figure 3. Average seasonal patterns of pneumonia (A) and diarrhea (B). Diarrhea deaths are split into subsets of cases with/without both fever and bloody stool, as well as typhoid and paratyphoid fever deaths. We defined pneumonia deaths using ICD-10 codes A37, H65-H68, H70, H71, J00-J22, J32, J36, J85, J86, P23, or U04. We defined diarrhea deaths using ICD-10 codes A00, A02-A09, and distinguished further based on symptoms reported in the VA (deaths exhibiting both fever and bloody stool; deaths not exhibiting both fever and bloody stool). We defined typhoid and paratyphoid fever deaths using ICD-10 code A01. Each horizontal axis represents an average yearly span from April to April. We determined seasonal patterns using monthly counts of death and modeled using Poisson regression. Rate ratios (RR) are calculated within each disease and are compared to annual minimum mortality in the month of April.

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Figure 3—figure supplement 1. Time series model by pneumonia and diarrhea total. Diarrhea deaths are split into subsets of cases with/without both fever and bloody stool, as well as typhoid and paratyphoid fever deaths. Pneumonia deaths are defined by ICD-10 codes A37, H65-H68, H70, H71, J00-J22, J32, J36, J85, J86, P23, or U04. Diarrhea deaths were defined by ICD-10 codes A00, A02-A09, and distinguished further based on symptoms reported in the verbal autopsy. Typhoid and paratyphoid fever deaths were defined by ICD-10 code A01. Each dashed vertical line designates December of each year. Data was modeled using a generalized additive model and Poisson regression, using monthly count of deaths from the Million Death Study. Each vertical dashed line designates December of each year.

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Figure 3—figure supplement 2. Average seasonal patterns of pneumonia deaths by adult age subset. Each horizontal axis represents an average yearly span from April to April. We determined seasonal patterns using monthly counts of death and modeled using Poisson regression. Rate ratios (RR) were calculated within each disease and were compared to annual minimum mortality in the month of April.

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Figure 4. Average seasonal patterns of pneumonia (A, C, E) and diarrhea lacking fever and bloody stool (B, D, F) deaths by child age subset. Counts of diarrhea with fever and bloody stool were too small to model. Each horizontal axis represents an average yearly span from April to April. We determined seasonal patterns using monthly counts of death and modeled using Poisson regression. Rate ratios (RR) were calculated within each disease and were compared to annual minimum mortality in the month of April.

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Figure 4—figure supplement 1. Time series model for (A) pneumonia and (B) diarrhea, by age subset. Diarrhea cases shown here are only those that did not exhibit fever and bloody stool. Data was modeled using a generalized additive model and Poisson regression, using monthly count of deaths from the Million Death Study. Each dashed vertical line designates December of each year.
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Figure 5. Map of India by state and Koppen-Geiger climate classification region. Original climate region data was extracted from Kottek et al. (2006). The Koppen-Geiger map of India was created using ArcGIS 10.4. The three climate regions shown include hot semi-arid (Bsh; including hot desert or Bwh), humid subtropical (Cwa; including subtropical highland or Cwb), and tropical savannah (Aw; including tropical monsoon or Am). The hot desert, subtropical highland, and tropical monsoon regions are incorporated into similar, adjacent climate regions given insufficient sample size. Briefly, the hot semi-arid region exhibits large fluctuations in annual temperature, has little annual precipitation, and is geographically proximal to deserts; the tropical savannah region is characterized by distinct dry-wet seasonal variation; and the humid subtropical region is defined by hot, humid temperatures and consistent rainfall throughout the year. AN = Andaman and Nicobar Islands. AP = Andhra Pradesh. AR = Arunachal Pradesh. AS = Assam. BR = Bihar. CH = Chandigarh. CG = Chhattisgarh. DD = Daman and Diu. DN = Dadra and Nagar Haveli. DL = Delhi. GA = Goa. GJ = Gujarat. HP = Himachal Pradesh. HR = Haryana. JH = Jharkhand. JK = Jammu and Kashmir. KA = Karnataka. KL = Kerala. LD = Lakshadweep. MH = Maharashtra. ML = Meghalaya. MN = Manipur. MP = Madhya Pradesh. MZ = Mizoram. NL = Nagaland. OD = Odisha. PB = Punjab. PY = Puducherry. RJ = Rajasthan. SK = Sikkim. TN = Tamil Nadu. TR = Tripura. UP = Uttar Pradesh. UT = Uttarakhand. WB = West Bengal.

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Figure 6. Average seasonal pattern of deaths from pneumonia by age group and Köppen-Geiger climate region. Each horizontal axis represents an average yearly span from April to April. We determined seasonal patterns using monthly counts of death and modeled using Poisson regression. Rate ratios (RR) were calculated within each disease and were compared to annual minimum mortality in the month of April. Given three regions also had a smaller sample size on which to model, they were bundled into regions with similar climatic characteristics (tropical monsoon into tropical savannah, hot desert into hot semi-arid, and subtropical highland into humid subtropical).

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Figure 6—figure supplement 1. Time series model for (A) pneumonia and (B) diarrhea by Köppen-Geiger climate region. Diarrhea cases shown here are only those that did not exhibit fever and bloody stool. Data was modeled using a generalized additive model and Poisson regression, using monthly count of deaths from the Million Death Study. Each checked horizontal line designates December of each year. Given three regions also had a smaller sample size on which to model, they were bundled into regions with similar climatic characteristics (tropical monsoon into tropical savannah, hot desert into hot semi-arid, and subtropical highland into humid subtropical). Each dashed vertical line designates December of each year.

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Figure 7. Dot map of child (1 month – 14 years) and adult (30–59 years) pneumonia deaths captured within the Million Death Study between June and August, by Koppen-Geiger climate region. The three climate regions shown include hot semi-arid (Bsh; including hot desert or Bwh), humid subtropical (Cwa; including subtropical highland or Cwb), and tropical savannah (Aw; including tropical monsoon or Am). The hot desert, subtropical highland, and tropical monsoon regions are incorporated into similar, adjacent climate regions given insufficient sample size to describe separately.

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Figure 8. Average seasonal pattern of deaths from diarrhea lacking fever and bloody stool by Köppen-Geiger climate region among children at ages 1 month to 14 years. Counts of diarrhea with fever and bloody stool were too small to model. Each horizontal axis represents an average yearly span from April to April. We determined seasonal patterns using monthly counts of death and modeled using Poisson regression. Rate ratios (RR) were calculated within each disease and were compared to annual minimum mortality in the month of April. Given three regions also had a smaller sample size on which to model, they were bundled into regions with similar climatic characteristics (tropical monsoon into tropical savannah, hot desert into hot semi-arid, and subtropical highland into humid subtropical).

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