

Spatial Analysis of Inequalities in Maternal and Child Mortalities in Pakistan

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Abstract: In developing countries, the death probability of a child and mother is more significant than in developed countries; these inequalities in health outcomes are unfair. The present study encompasses a spatial analysis of maternal and child mortalities in Pakistan. The study aims to estimate the District Mortality Index (DMI) and measure the inequality in maternal and child mortality across Pakistani districts. This study used micro-level household datasets from multiple indicator cluster surveys (MICS) to estimate the DMI. This study utilized spatial autocorrelation tests to determine the magnitude and location of the spatial dependence of the clusters with high and low mortality rates. The findings of the Local Indicator of Spatial Association (LISA) and Moran's test confirmed spatial homogeneity in all mortalities among the districts in Pakistan. The H-H clusters of maternal mortality and DMI were in Baluchistan, and the H-H clusters of child mortality were seen in Punjab. The findings reveal a significant disparity in DMI and spatial relationships among all mortalities in Pakistan's districts. Additionally, spatial proximity among individuals who are at risk of death occurs in areas with elevated mortality rates. Policymakers may mitigate these mortalities by focusing on vulnerable zones and implementing measures such as raising public awareness, enhancing healthcare services, and providing equitable funding for the health sector.

Keywords: District Mortality Index; Health outcomes; spatial autocorrelation; spatial heterogeneity; Hot/Cold spot.

1. Introduction:

At the midpoint of the Sustainable Development Goal (SDGs) era, developing countries are still off track to achieve the desired targets. For SDGs targets of 2030, 54 countries will be short of achieving the target of child mortalities and 63 other countries will not be able to reach the target of Neonatal Mortality Rate (NMR) (UNIGME, 2023). There are huge geographical variations in maternal and child mortalities around the globe. For instance, the majority of maternal, neonatal, and child deaths have occurred in low-income and lower-middle-income countries (World Health Organization, 2023). The death probability of a child and maternal mortalities in developing countries is greater by eight times and nineteen times respectively as compared to developed countries (World Health Organization, 2015). Around 87% of global maternal deaths and 80% of under-five deaths have taken place in Sub-Saharan Africa (SSA) and Asia, respectively. A child born in a developing country is less likely to survive as compared to a child born in a developed country (World Health Organization, 2022).

In Sub-Saharan Africa (SSA), MMR is 133 times greater as compared to Australia, New Zealand, and Europe. Following SSA, South Asia accounts for 17% of the total maternal

deaths worldwide (UNICEF & World Health Organization, 2024). The prevalence of most maternal and child mortalities in some regions of the globe is indicative of disparities in the availability of high-quality healthcare facilities, hence underscoring the socioeconomic divide between affluent and impoverished populations. Due to such substantial regional differences, the interest of researchers and policymakers has grown in finding spatial disparities in maternal and child mortality, especially in low- and middle-income countries (LMIC). Pakistan is also facing the challenge of spatial inequality in maternal and child mortality and stands 3rd out of the top 10 fragile countries with the highest maternal and child death burden throughout the globe (World Health Organization, 2023). Among the South Asian Association for Regional Corporation (SAARC) countries, it has 3rd highest rank in MMR. (Aziz et al., 2020) explored that Pakistan's pregnancy outcomes are the worst among the six LMICs.

In the realm of health economics, several indices have been estimated to explore the spatial disparities in health outcomes and health services coverage. This study also combines all (child and maternal) mortality into a composite index to investigate the overall picture of mortality in Pakistan. The composite metric is useful in the measurement and comparison of geographical inequalities in mortality. Besides, it allows the researchers and public health practitioners to choose the size/unit of analysis such as household, union council, district, and province.

Methodology: This study focuses on the spatial analysis of mortalities across districts in Pakistan's four provinces, namely Sindh, Punjab, Baluchistan and, Khyber Pakhtunkhwa (KP), as well as Federally Administrated Tribal Areas (FATA). This study is based on the micro-level household datasets of Multiple Indicator Cluster Survey(s) (MICS) conducted in 2018–19 by the government of Pakistan in collaboration with the United Nations International Children’s Emergency Fund (UNICEF) (Bureau of Statistics GoP, 2021). The sample size was 141 districts in total. The outcome variable is “*DMI*” which is a composite of four child mortalities and three maternal mortalities.

Table 1. Description of mortalities used in the construction of the District Mortality Index (DMI)

S. No.	Mortality name	Acronyms	Description
1	Neonatal mortality rate	NMR	Probability of dying within the first month of life
2	Post-neonatal mortality rate	PNMR	Difference between infant and neonatal mortality rates
3	Infant mortality rate	IMR	Probability of dying between birth and the first birthday
4	Child mortality rate	CMR	Probability of dying between the first and the fifth birthday
5	Died during pregnancy	DDP	Deaths of women aged 15-49 during pregnancy, excluding accidents and acts of violence, per 100,000 live births
6	Died during childbirth	DDCB	Deaths of women aged 15-49 during childbirth, excluding accidents and acts of violence, per 100,000 live births
7	Died within two months	DW2M	Death of women aged 15-49 within 2 months after pregnancy termination, excluding accidents and acts of violence, per 100,000 live births

Source: Multiple Cluster Indicators Survey (MICS) 2018 and 2019

Estimation of district mortality index: DMI is calculated using the procedure proposed by the WHO for evaluating the Urban Health Index (UHI) (Weaver et al., 2014). To convert the mortality rate into a dimensionless number I^S between 0 and 1, the mortality rate was standardized by taking the difference of mortality's actual value (I) from its lowest value divided by the range of mortality rate denoted in Eq. (2.1) as

$$I^S = \frac{I - \min^*(I)}{\max(I) - \min^*(I)} \dots\dots\dots (2.1)$$

Where I^S is the standardized mortality rate and $0 < I^S < 1$ condition is fulfilled. In the second step, all standardized indicators have been accumulated into a single metric by taking their geometric mean.

Global Moran's I and Local indicators of spatial autocorrelation: To examine the spatial relationship in maternal and child mortalities among adjacent districts and identify the location of this spatial association, the present study used Global Moran's I and local indicators of spatial association (LISA) (Anselin, 1995).

2. Result: Spatial variations of DMI and associated mortalities in Pakistan

Figure 1 displays the visual distribution of child mortalities (panels a to d), maternal mortalities (panels e to g), and district mortality index (panel h).

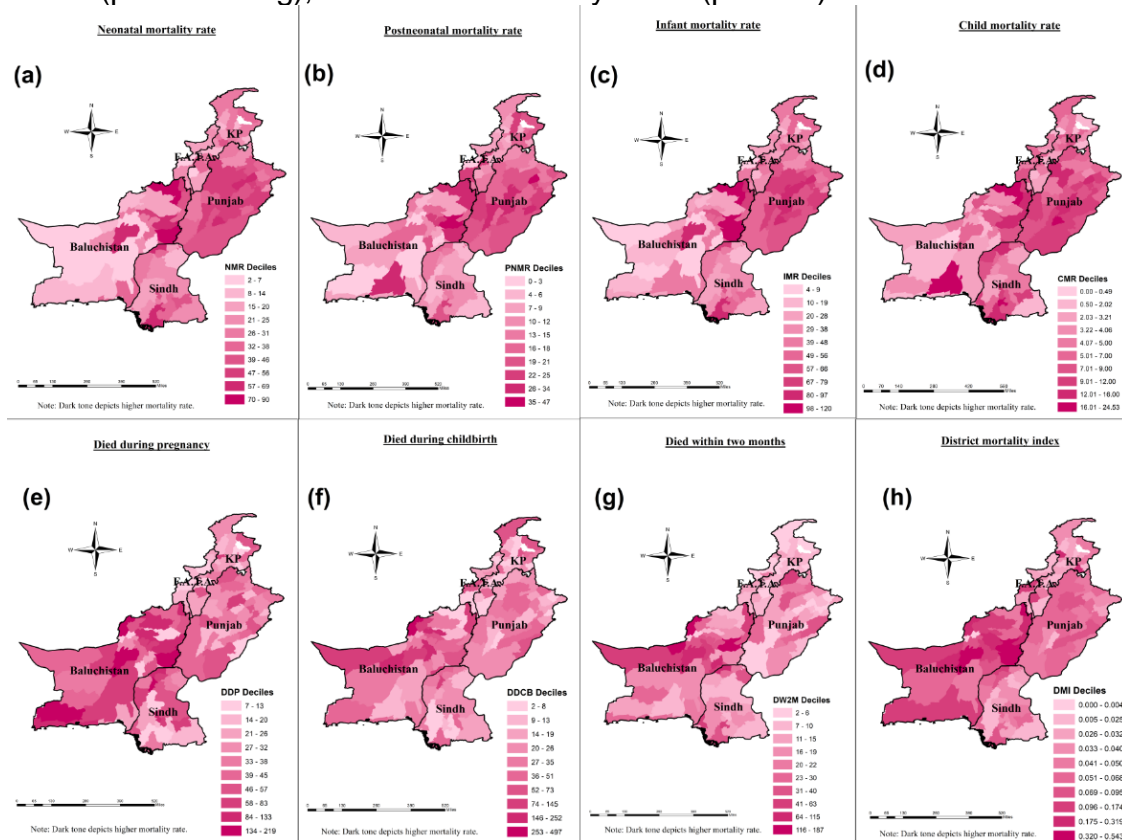


Fig 1. Map for distribution of mortalities and DMI in 142 districts of Pakistan Maps visualize (a) neonatal mortality (b) Post neonatal mortality (c) Infant mortality (d) child mortality (e) Died during pregnancy (f) Died during childbirth birth (g) Died within two months after pregnancy termination (h) District mortality index. (the map was created by the author using ArcGIS Pro (version 10.8)).

It is shown that child mortalities have a clear spatial pattern of high rates in districts in Punjab province, which means that these mortalities are more severe in Punjab. Both the highest and lowest rates of child (NMR, PNMR, IMR, and CMR) mortalities were clustered in the districts of Baluchistan province, which indicates that the mortality gap is higher in Baluchistan as compared to Punjab, KP, Sindh, and FATA. Unlike child mortalities, maternal mortalities (DDP, DDCB, and DW2M) have shown different spatial patterns. All three maternal mortalities with high rates were clustered in districts of Baluchistan province, followed by Punjab (Figures 1e to 1g). Both Baluchistan and Punjab provinces have displayed clear spatial clusters of high DMI scores; however, these scores were found to be slightly higher in the districts of Baluchistan as compared to Punjab and the rest of the provinces. Moreover, figure 1h shows that KP, Sindh, and FATA have moderate spatial clusters of district mortality index scores.

Hot spot and cold spot zones for mortalities in Pakistan

Spatial association and clustering of child mortalities in Pakistan

The global Moran index value for NMR, PNMR, IMR, and CMR in Table 2 demonstrates a positive spatial autocorrelation among adjacent districts. All the associations are significant (with 999 permutations and a pseudo-p-value of 0.00) which shows 31%, 30%, 35%, and 22% homogeneity among the mortality rates of the neighboring districts respectively. To identify the location of the association among the mortalities, a LISA cluster map is drawn (Figure 2). The H-H clusters of child mortalities were mostly located in central and east-western Punjab and a few districts from eastern Baluchistan whereas the significant L-L clusters were mostly spotted in Baluchistan and lower districts of KP province (Figure 2a to 2d). Moreover, the results also displayed spatial outliers (districts with high (low) mortality rates are surrounded by districts with Low (High) mortality rates) of child mortalities. Most of the spatial outliers (with H-L and L-H characteristics) in child mortalities were situated in Baluchistan and a few districts of Punjab.

Table 2. Spatial autocorrelation for all mortalities along DMI measured through Moran's I

Variable	Moran's I	E(I)	SD(I)	Z-scores	P-values
Neonatal mortality rate	0.316	-0.0071	0.00261	6.325	0.000
Post-neonatal mortality rate	0.301	-0.0071	0.00259	6.056	0.000
Infant mortality rate	0.352	-0.0071	0.00261	7.026	0.000
Child mortality rate	0.226	-0.0071	0.00260	4.580	0.000
Died during pregnancy	0.120	-0.0071	0.00249	2.564	0.010
Died during childbirth	0.073	-0.0071	0.00179	1.894	0.058
Died within two months	0.1887	-0.0071	0.00227	4.109	0.000
District mortality index	0.303	-0.0071	0.00243	6.291	0.000

Source: Author's calculation based on multiple indicator cluster survey (MICS), 2018-2019.

Spatial association and clustering of maternal mortalities in Pakistan

The global Moran index for maternal mortality rates in Table 2 indicates a moderately weak correlation among the districts of Pakistan, i.e., the values of Moran's I for DDP, DDCB, and DW2W were calculated as 12%, 7%, and 19%, respectively. Moran's I exhibited spatial homogeneity in the maternal mortality rates among districts of Pakistan.

Concerning DDP, the H-H zones were significantly dispersed among districts in Baluchistan, but most of the host spot zones were spotted in southern Baluchistan (Figure 2e). The highest clusters of DDCB and DW2W were located in north-western Baluchistan and south Baluchistan. The cold spot zones for maternal mortality rates were found in districts of KP province.

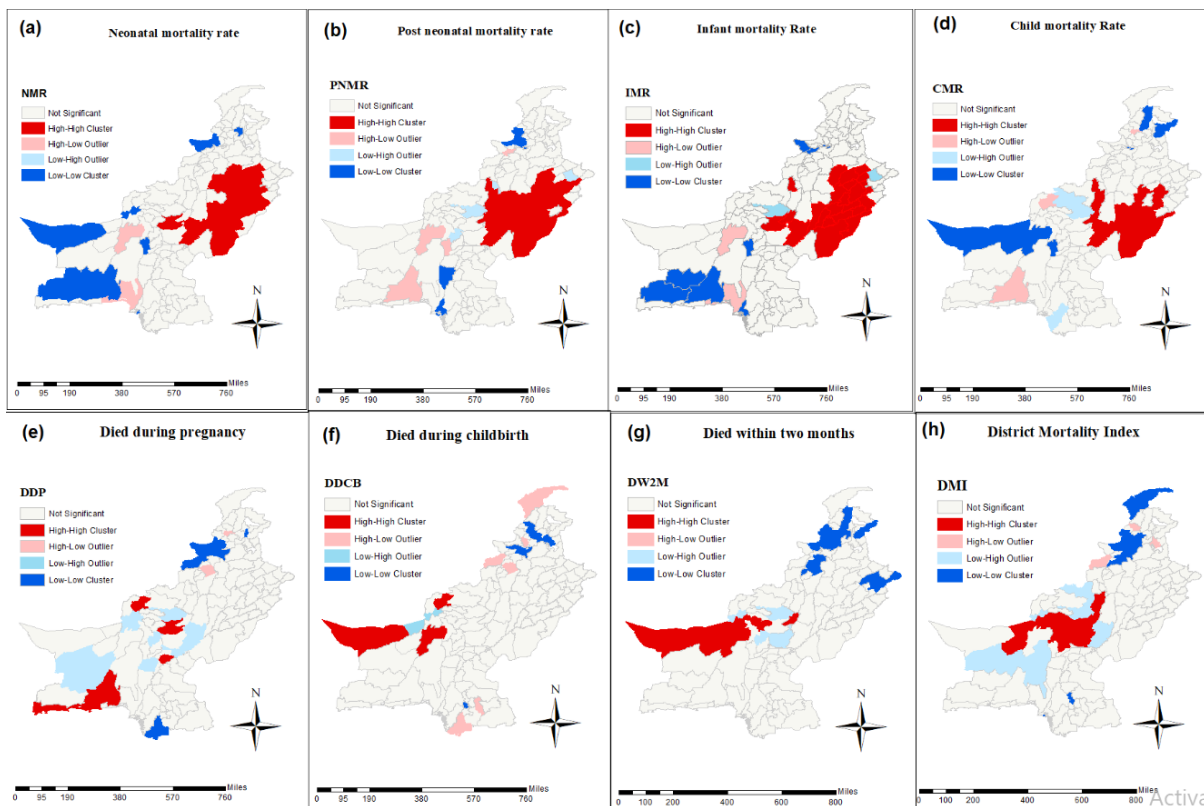


Fig 2. Univariate spatial analysis of LISA test of (a) neonatal mortality (b) Post neonatal mortality (c) Infant mortality (d) child mortality (e) Died during pregnancy (f) Died during childbirth (g) Died within two months after pregnancy termination (h) District mortality index. The red color represents the HH cluster and the blue color represents the LL clusters of mortalities. (these maps were created by the author using the GeoDa application).

Spatial association and clustering of DMI

The Global Moran's I test for DMI scores was measured at 30% (with a pseudo-p-value of 0.00 and 999 permutations), denoting a significant association among the mortalities of contiguous districts (Table 2). The LISA analysis of DMI shows that significant hotspot (H-H) areas were located among districts of Baluchistan, especially in southern and central Baluchistan, and cold spot (L-L) zones were spotted in the northern and western districts of KP province (Figure 2h). The low-low clusters of DMI were also positioned in the central part of Sindh province.

3. Discussion and Conclusion:

The current study quantifies the spatial disparity in maternal and child mortality and reveals extreme spatial heterogeneity in maternal, neonatal, infant, and child mortalities in Pakistan. Similar findings were found in Brazil (Sousa et al., 2010), India (Mishra et al.,

2021) , 54 African countries (Yaya et al., 2021), and (Sartorius & Sartorius, 2014), which revealed global subnational inequality in IMR through the Theil index. Also, despite being the most developed province in terms of healthcare facilities and literacy, Punjab has the highest child mortality due to its high population density and highest birth rate (National Institute of Population Studies Pakistan, 2017-18). Maternal mortality and overall DMI scores were highest in Baluchistan as compared to other provinces, showing heterogeneity in health outcomes across the districts of Pakistan. Our study findings also revealed that Sindh and KP are relatively better off in terms of DMI scores, with relatively lower maternal and child mortality rates (Bhutta et al., 2013).

The findings of this study provided useful insights into the geographical clustering and randomness of districts in Pakistan concerning all mortalities and the district mortality index. The Global Moran index scores of maternal mortality indicators exhibited positive spatial autocorrelation, resulting in spatial homogeneity in maternal mortality among the districts of Pakistan. The results of the LISA showed that most of the contiguous districts with higher maternal mortality rates were in Baluchistan. These findings were in line with (Sarwar, 2021) who found L-L clusters of maternal health service utilization in Baluchistan. Moreover, concerning overall mortalities (DMI), scores denote significant and moderate association among the mortalities of contiguous districts. The LISA cluster map of DMI showed that H-H clusters of overall mortalities were located among districts of Baluchistan, especially in the districts of central Baluchistan. The L-L clusters were spotted in the districts of the upper and central districts of KP and the central districts of Sindh province. Baluchistan is the most impoverished region, and a dearth of healthcare facilities could potentially contribute to higher maternal and overall mortality rates. These fatalities could be prevented with timely and appropriate medical care.

These findings are of high value to policymakers and health financing bodies and advocate for prioritizing Baluchistan (due to the presence of H-H clusters of maternal mortality) and Punjab (due to the presence of H-H clusters of under-5 mortalities). We recommend that the government allocate additional funds to improve the utilization and infrastructure of maternal health services in Baluchistan, thereby reducing maternal mortality in the province. The government may overcome the high child mortality by improving the financial status of people falling in the poorest wealth index quintile, and emphasis should be given to educationally and economically marginalized mothers, particularly those living in remote communities where child healthcare utilization is comparatively low.

Abbreviations

WHO: World Health Organization; SDG: Sustainable Development Goal; SSA: Sub-Saharan Africa; SAARC: South Asian Association for Regional Cooperation; DMI: district mortality index; FATA: Federally Administered Tribal Areas; KP: Khyber Pakhtunkhwa; UNICEF: United Nations International Children's Emergency Fund; MICS: Multiple Indicators Cluster Survey; UHI: Urban Health Index; LISA: Local Indicator of Spatial Association.

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