Predictors and disparities in neonatal and under 5 mortality in rural Pakistan: cross sectional analysis

Zahid Memon,[a] Daniel Fridman,[b] Sajid Soofi,[a] Wardah Ahmed,[a] Shah Muhammad,[a] Arjumand Rizvi,[a] Imran Ahmed,[a] James Wright,[b] Simon Cousens,[c] and Zulfiqar A. Bhutta[a,b,c,*]

[a]Center of Excellence in Women and Child Health, The Aga Khan University, Karachi, Pakistan
[b]Centre for Global Child Health, The Hospital for Sick Children, Toronto, ON, Canada
[c]London School of Hygiene and Tropical Medicine, United Kingdom

The Lancet Regional Health - Southeast Asia 2023;15: 100231

Published Online 20 June 2023

https://doi.org/10.1016/j.lansea.2023.100231

Summary

Background Adopted in 2015, the sustainable development goals (SDGs) have set specific targets (SDG 3.2) for countries to reduce their neonatal mortality rate (NMR) to below 12 deaths per 1000 live births and under 5 mortality rate (U5MR) to below 25 deaths per 1000 live births by 2030. For Pakistan to achieve these targets, there is a need to measure these rates and understand the predictors of child mortality at sub-national level. Launched in 2016, the *Umeed-e-Nau* (UeN) or New Hope project is based on scaling up proven and effective Maternal and Newborn Child Health (MNCH) interventions in 8 of the highest burden districts of the country, using existing public sector platforms in Pakistan at both the community and facility level. The primary aim of the project is to reduce perinatal mortality in these districts by 20% from baseline.

Methods We report overall neonatal and post neonatal mortality rates for the two years preceding the UeN baseline household survey. Rates were calculated using the synthetic cohort probability method and predictors of neonatal and post neonatal mortality examined using Cox regression. To investigate spatial variations in the mortality rates, we calculated Moran's I at the district level using predicted probabilities of mortality. Finally, we create district level maps of predicted under 5 child mortality using a stochastic partial differentiation approach.

Findings A total of 26,258 children contributed to the analysis of mortality with 838 deaths in the neonatal period and 2236 under-5 deaths during the observation period from March 1, 2015 to March 17, 2017. Overall, we estimated the NMR to be 29.2 per 1000 live births (95% CI: 26.9–31.4) and the U5MR to be 86.1 per 1000 live births (95% CI: 85.5–86.8). We found evidence of within-district geospatial clustering of under 5 mortality ($P < 0.0001$) and that social factors (poverty, illiteracy, multiparity), poor coverage of community health workers and distance from health facilities were strongly associated with child mortality.

Interpretation Important factors associated with neonatal and post-neonatal mortality in our study population included maternal education, parity, household size and gender. Additionally, antenatal care coverage (at least 4 visits) was specifically associated with neonatal mortality only, whereas, LHW coverage and distance to health facility were strongly associated with post-neonatal mortality. These findings emphasise the need for comprehensive, multisectoral strategies to be implemented for future maternal and child health programs and outreach services in rural areas.

Funding The study was funded by an unrestricted grant from the Bill & Melinda Gates Foundation to the Aga Khan University (Grant OPP 1148892).

Keywords: Neonatal mortality; Post-neonatal mortality; Survival analysis; Geospatial

Introduction

The first twenty-eight days of life (the neonatal period) are critical for child survival. Of the 5.2 million under five deaths estimated for the year 2019, 2.4 million occurred in the neonatal period. Children in low- and middle income countries (LMIC) are nine times more likely to die in the first month of life than children in high income country (HIC) settings.[1,2]

*Corresponding author. Distinguished University Professor and Founding Director, Institute for Global Health and Development, The Aga Khan University, South Central Asia, East Africa and United Kingdom, Karachi 74800, Pakistanor Robert Harding Chair in Global Child Health and Policy, SickKids Centre for Global Child Health, The Hospital for Sick Children, Toronto, On M6S 1S6, Canada.
E-mail addresses: zulfiqar.bhutta@aku.edu, zulfiqar.bhutta@sickkids.ca (Z.A. Bhutta).

Research in context

Evidence before this study

We undertook a systematic review of published studies and reports evaluating newborn and under 5 child mortality in Pakistan using broad review terms such as 'newborn", "child", "under 5 child", "mortality", "deaths", "drivers" and "risk factors". In the absence of vital registration systems, much of the information on newborn and child mortality in Pakistan is derived from national surveys such as demographic and health surveys and for infants, multiple indicator cluster surveys, and maximally provides information at provincial level. Two additional studies of risk factors were conducted in selected populations over three decades ago and highlighted the contribution of poverty and lack of health services as important contributors to neonatal deaths. There are no recent studies evaluating patterns and drivers of newborn or child mortality at sub-provincial or district level. Available information identifies the importance of poverty, lack of maternal education, rurality, lack of health services and poor care seeking patterns as important predictors of child mortality.

Added value of this study

Our baseline study of newborn and child mortality patterns at district level shows important variations in mortality patterns between and within the eight high-burden districts of rural Pakistan. We corroborated the important correlations between lack of maternal education, higher parity, and household size as well as poor antenatal care coverage (at least 4 visits) with respective newborn and under 5 child deaths at population level. Additionally, poor LHW program coverage in respective households and longer distance to health facilities were strongly associated with excess under five mortality in these districts.

Implications of all the available evidence

These findings further strengthen the need for comprehensive, multi-sectoral strategies to reduce the high rates of neonatal and under 5 child mortality in Pakistan. These should include strategies to alleviate poverty, improve maternal education and empowerment, especially reproductive health services and family planning. The baseline study also corroborates the design of the UeN project to address community-based demand-creation and quality of maternal and child health outreach services through the LHW program in high burden rural areas of Pakistan including antenatal care, childhood immunizations and care seeking for illnesses.

Pakistan has a neonatal mortality rate (NMR) of 41 deaths per 1000 live births, one of the highest in the world, and an under-5 child mortality rate (U5MR) of 67 deaths per 1000 live births.[2] Previous studies reveal large socioeconomic disparities, as well as an urban-rural divide,[3–5] with evidence of an association between low levels of maternal education and high neonatal mortality.[6]

Adopted in 2015 by United Nations member states, the Sustainable Development Goals have set a target for countries to reduce their NMR to below 12 deaths per 1000 live births and reduce their U5MR to below 25 deaths per 1000 live births by 2030 (SDG 3.2). The majority of U5 and neonatal deaths are preventable and both health facility-based and community-based interventions have been shown to reduce these deaths in high-risk populations.[6–9] For Pakistan to achieve the SDG targets, there is a need to understand the factors associated with child mortality and how mortality varies within districts.[10]

While interventions such as vaccinations, improved nutrition, and access to healthcare have helped reduce both neonatal and U5 mortality rated globally, the trends in responsiveness to interventions differ between neonates and older children under 5 (U5). Improved obstetric care during delivery, and management of preterm birth complication are particularly important in reducing neonatal deaths. Post neonatal U5 deaths are more responsive to vaccinations, access to clean water and sanitation and improved nutrition. Thus, to reduce U5 mortality a multifaceted approach to prevention and management is required.[11,12]

Initiated in 2016, the *Umeed-e-Nau* (UeN) program is being conducted in 8 high-burden rural districts of Pakistan. It involves the roll-out of proven, effective Maternal, Newborn and Child Health (MNCH) interventions at scale, at both the community and facility level, using existing health system platforms. The impact of the program is being evaluated using a quasi-experimental design[13] (Clinicaltrials.gov identifier: NCT04184544). The objective of this paper is to analyze data from the UeN baseline survey to obtain district-level estimates of NMR and U5MR for the 8 districts. Additionally, we investigate the factors associated with child mortality and investigate the spatial distribution of child mortality within each district.

Methods

The sample size for the survey was estimated based on mortality rates from the Pakistan Demographic Health Survey 2012–2013 for the rural population,[2] (Perinatal Mortality Rate (PMR) = 75 per 1000 total births; post-neonatal mortality rate (PNMR) = 19 per 1000 live births). To detect a potential 20% reduction in perinatal mortality from baseline to the end of study with a power of 80%, a type I error of 5%, design effect of 1.515 and assuming a 90% response rate, we estimated that a sample size of 38,792, households was required for the survey at each time point (for details of the methodology refer to the UeN published protocol).[13] The survey used a two-stage, stratified, cluster sampling design and included only households in the targeted districts with a married woman of reproductive age (MWRA, 15–49 years old). All sampled women were interviewed to record their full pregnancy history as most pregnancies in Pakistan mainly occur within wedlock.[14] In each household, the woman with the youngest surviving under-5 child was selected to answer questions related to MNCH knowledge and practices. The survey excluded households that had lived in the target district for less than three months as well as those that did not intend to live in the district for a prolonged time.

Clusters were defined as Lady Health Worker (LHW) covered areas of approximately 1000 population or equivalent populations in non-LHW covered areas, with information on the sampling frame obtained from the district health authorities. At the first sampling stage, clusters were randomly selected from the list of all clusters in each study district. At the second stage, households with MWRAs were identified and 20 such households sampled using systematic random sampling technique. A total of 250 clusters per district with 20 households sampled per cluster provided the required sample size. Of the 250 clusters, 150 had LHW coverage, and 100 were uncovered. To ensure data quality and reliability, all the information was gathered using handheld electronic devices (Samsung model SM-T285). Data collection was undertaken, after obtaining verbal consent, by trained data collectors supervised by a technical team and supervisors, independent of the intervention implementing team. Data from handheld devices were directly uploaded to the main server of the data management unit at AKU. GIS co-ordinates of households were auto generated. The data gathering application had real time monitoring of the location of the data points, timing of the data collection, and duration for each form. Information was displayed on the project specific dashboard only accessible to survey data managers. In the case of outlying measurements, queries were sent back to the team leader and relevant data collector for necessary action within 24 hours. The analyses conducted for this manuscript are within the remit of the ethical approval provided and participant consent. The Ethical review committee (ERC) of the Aga Khan University provided the ethical approval for this study. Additionally, clearance was obtained from National Bioethics Committee (NBC) of the Government of Pakistan.

This survey data included full pregnancy histories from all MWRA in each household, from which U5MR and NMR were estimated. Data was collected between May 16, 2017 and July 17, 2017. We used data from all children under 5 years age for at least some of the period between March 1, 2015 and March 17, 2017, to estimate U5MR for the two years preceding the survey. Rates were calculated using the synthetic cohort method used by the Demographic and Health Surveys (DHS). In this method the overall probability of dying is calculated by combining the probability of death for each age specific interval.[15,16] We also report U5MR and NMR disaggregated by district, LHW coverage, gender, size of household, maternal age, maternal education, parity, distance to a district headquarters hospital (DHQ) or taluk (sub district) headquarters hospital (THQ) and wealth tercile. Wealth terciles and distance to facility were estimated from the raw dataset, and details of the methods can be found in the Appendix.

Factors associated with neonatal and post-neonatal mortality were investigated using Cox regression. Time-at-risk was measured from the latest of either the beginning of the observation period (March 1, 2015) or the child's date of birth until the earliest of either date of death, date of interview, or 28 days of age or from 29th day to fifth birthday (for NMR and PNMR, respectively).

Maternal age was analysed as a dichotomous variable; under 18 years or 18 years and over. Maternal education was categorized as none (reference category), primary (1–5 years) or secondary (≥6 years of education). Parity was categorized as primipara (women who had given birth once), multipara (women who had given birth two, three or four times) or grand multipara (women who had given birth five or more times). Wealth tertiles were generated by principal component analysis using households' characteristics and household assets. Household size was analysed as a dichotomous variable; 6 or fewer members versus 7 or more members. Antenatal coverage (ANC4) was categorized as less than four antenatal care visits or four or more than four antenatal care visits.

The model-building process involved estimating univariate associations for each covariate, and initially retaining all those with P-values less than 0.2. We used backwards elimination with a P-value threshold of 0.1 to determine which variables to retain in the final model. Estimates of mortality rates and analyses of predictors of child mortality were conducted using STATA 15.1 and all analyses account for the survey design including cluster sampling and sampling weights.

To investigate systematic spatial variations in the mortality rates, we analyzed the predicted probability of mortality. For each district we used Moran's I to test if deaths were randomly distributed through space, or if there was evidence of spatial clustering. To calculate Moran's I, we aggregated individual-level observations, calculating the mean for each survey cluster and assigning coordinates based on the centroid of that cluster's household-level observations. Survey clusters were defined as neighbours if their centroids were within 15 km of each other. Positive values of Moran's I indicate that observations that are geographically closer have more similar values compared to those from clusters further away. We simulated the distribution under the null hypothesis (I = 0) using a Monte Carlo permutation method. Using a Bonferroni adjustment to account for multiple comparisons and $\alpha = 0.05$, we used a threshold for statistical significance of $P\ (I = 0) < \alpha/n = 0.05/8 = 0.00625$.

Finally, to evaluate geographic disparities within districts, we mapped the predicted mortality rates from our survival models, aggregated at the survey-cluster level, using a stochastic partial differentiation approach (SPDE). Details of these methods can be found in the Appendix. The geospatial analysis was conducted using R 3.6.1.

Role of funding source

The funding agency had no role in the data collection and analysis. The funding agency had no role in writing and decision to submit this paper.

Results

The cross-sectional data was collected from eight districts in three of the four provinces in Pakistan: Muzaffargarh and Rahim Yar Khan in Punjab; Jafferabad, Nasirabad and Lasbella in Baluchistan; and Badin, Sanghar, and Qambar Shahdadkot in Sindh (Fig. 1). The overall response rate was 92.7%. All the eligible household were visited for the survey, but the remaining respondents did not participate because they were not available during the interview). The analysis included only the completed households.

A total of 26,258 children contributed to the analysis of mortality with 838 deaths in the neonatal period and 2236 under-5 deaths during the observation period from March 1, 2015 to March 17, 2017. Table 1 presents the estimated neonatal and under-5 mortality rates by district and socio-demographic factors.

Overall, we estimated the NMR as 29.2 per 1000 livebirths (95% CI: 26.9–31.4) and the U5MR to be 86.1 (95% CI: 85.5–86.8). Lasbella district had the lowest estimated NMR (23.0, 95% CI: 12.6–33.4), while Jaffarabad district had the highest NMR (40.7, 95% CI: 39.9–41.4). Sanghar district had the lowest estimated U5MR (65.9, 95% CI: 60.7–71.0), while Lasbella district had the highest U5MR (111.7, 95% CI: 98.5–125.0). Table 2 shows the perinatal mortality rates by district. Overall, we estimated the perinatal mortality rate of 51.3 (95% CI: 47.8–55.0).

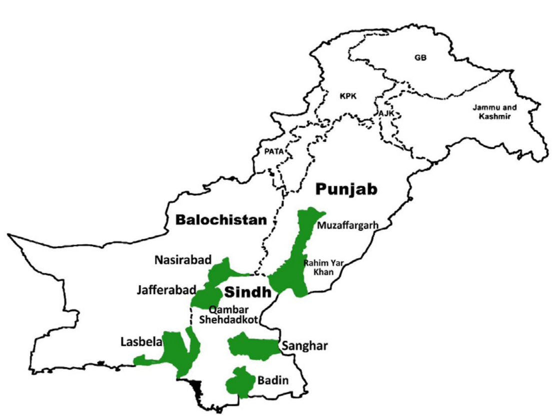

Fig. 1: Map of the UeN study area.

The results of the univariate analysis of factors associated with mortality are shown in Fig. 2a and b. Results of the final Cox regression models are in Tables 3 and 4. The final models for neonatal and post neonatal mortality both included five covariates. Both models included maternal education, parity, and gender. In addition, the neonatal model included wealth tercile and ANC4 coverage. While the post neonatal model included distance to facility and LHW coverage. Lack of maternal education was associated with higher mortality rates. Compared to mothers with secondary education, mothers with no education had a neonatal mortality hazard ratio (NMHR) of 1.56 (95% CI: 1.09–2.251) and a post neonatal mortality hazard ratio (PNMHR) of 1.60 (95% CI: 1.15–2.22). Higher parity was associated with increasing mortality rates. Compared to children of primiparous women, children of multiparous women had an NMHR of 2.89 (95% CI: 1.99–4.21) and a PNMHR of 2.87 (95% CI: 2.13–3.88). Those in the middle wealth tercile had higher neonatal mortality than those in poor tercile (NHR: 1.47, 95% CI: 1.16–1.87. Female newborns had lower mortality than males (NMHR: 0.77, 95% CI: 0.64–0.93). Conversely, in the post-neonatal period mortality was higher in female children than males (PNMHR: 1.18, 95% CI: 1.02–1.37).

Neonatal mortality was higher among mothers who reported fewer than four antenatal care visits, compared to those who reported at least four ANC visits (NMHR: 1.51, 95% CI: 1.17–1.95; Households with no LHW coverage had higher post neonatal mortality (PNMHR: 1.48, 95% CI: 1.24–1.78), but no evidence of an association was seen for neonatal mortality. Finally, households farther than 1 km from a DHQ or THQ had higher post neonatal mortality compared to those who lived closer (PNMHR: 2.06, 95% CI 1.23–3.46).

In assessing the geospatial distribution of mortality within each district, the calculated Moran's I for the predicted probability of mortality was positive in all districts for the U5 models, indicating strong evidence of spatial variations in mortality rates ($P < 0.0001$ for all districts). For neonatal mortality, the geospatial variations were less pronounced that for U5 mortality in most districts, with smaller values of Moran's I and larger P-values. Full details of Moran's I estimates are in the Appendix Table A2.

Fig. 3a and b shows maps of the mortality predictions for the districts with the highest and lowest U5MR. Maps for all districts can be found in the Appendix. From these maps we can see that predicted child mortality was mostly, but not always, lower in

Item	Neonatal mortality count	Neonatal estimated mortality rates (95% CI)	U5 mortality count	Under 5 estimated mortality rates (95% CI)
District				
Jafferabad	87	40.7 (39.9–41.4)	199	92.8 (79.3–106.3)
Nasirabad	68	36.0 (31.1–40.9)	162	93.2 (66.4–119.9)
Lasbella	63	23.0 (12.6–33.4)	274	111.7 (98.5–125.0)
Muzaffargarh	108	25.5 (19.3–31.6)	384	110.7 (101.4–119.9)
Rahim Yar Khan	110	28.6 (25.7–31.6)	260	69.0 (59.1–78.9)
Badin	160	35.6 (29.4–41.7)	297	70.4 (65.8–75.1)
Sanghar	103	26.3 (22.8–29.7)	244	65.9 (60.7–71.0)
Qambar Shahdadkot	145	39.9 (34.0–45.8)	306	85.6 (79.7–91.5)
Variables				
Maternal age				
Under 18	6	38.0 (4.7–71.3)	23	68.0 (24.4–111.6)
18 and over	776	29.1 (26.0–32.2)	2087	86.7 (83.2–90.2)
Maternal education				
None	630	31.3 (29.9–32.6)	1783	95.1 (94.5–95.8)
Primary	77	29.9 (24.3–35.4)	165	69.7 (62.9–76.6)
Secondary+	69	18.0 (17.3–18.7)	159	49.2 (49.2–49.3)
Parity				
Primipara	75	14.5 (11.4–17.6)	182	34.9 (32.2–37.6)
Multipara	418	31.1 (30.2–32.0)	1158	96.3 (91.4–101.3)
Grand multipara	290	37.4 (30.7–44.1)	771	115.8 (107.0–124.7)
Gender				
Boy	442	32.4 (32.3–32.6)	1078	84.5 (83.8–85.1)
Girl	338	25.7 (21.9–29.5)	1030	87.9 (86.9–88.8)
Wealth tercile				
Poor	218	24.6 (20.3–28.9)	649	81.8 (66.7–97.0)
Middle	292	33.9 (31.7–36.0)	741	93.1 (92.5–93.7)
Rich	272	29.2 (27.9–30.5)	718	83.5 (74.5–92.6)
Household size				
6 and under	360	25.9 (20.5–31.3)	926	76.6 (71.4–81.7)
7 or more	415	33.7 (32.4–34.9)	1177	98.6 (86.1–111.0)
Distance to facility				
Less than 1 km	35	25.0 (0.3–49.7)	60	47.8 (41.2–54.3)
1 km or greater	728	29.9 (28.6–31.2)	1950	87.2 (84.7–89.7)
LHW status of household				
LHW uncovered	303	28.3 (25.2–31.4)	1008	105.9 (104.9–106.9)
LHW covered	472	29.7 (27.8–31.6)	1101	74.2 (71.6–76.9)
ANC4				
No	570	31.1 (27.7–34.5)	1552	91.7 (87.5–96.0)
Yes	144	20.6 (13.5–27.7)	424	72.7 (65.5–79.9)
Overall		**29.2 (26.9–31.4)**		**86.1 (85.5–86.8)**

Table 1: **Estimated neonatal and under 5 mortality rates (deaths/1000 live births).**

more populous urban areas of districts and those closer to main hospitals.

Discussion

Our analysis confirms that substantial disparities in neonatal and child mortality exist between and within provinces at the district level in rural Pakistan. Our estimates of U5MR were higher than national estimates but NMR estimates were lower.[2] This may reflect potential under-reporting of neonatal deaths as well as the possibility that these high burden districts are still at a higher level of under-5 mortality than the national average. In either case these rates are well above SDG targets.

Several strengths and limitations should be recognized in our analysis. Although this survey was not nationally representative it is representative at

District	Perinatal mortality counts	Estimated perinatal mortality rates (95% CI)
Jafferabad	149	64.6 (54.4–76.5)
Nasirabad	157	77.3 (61.9–96.2)
Lasbela	188	53.7 (45.0–64.0)
Muzaffargarh	216	46.5 (39.9–54.1)
Rahim YK	207	48.2 (40.1–57.8)
Badin	284	64.8 (55.9–75.1)
Sanghar	195	45.8 (39.1–53.4)
Qambar Shahdadkot	301	64.3 (55.8–74.0)
Overall	1697	51.3 (47.8–55.0)

***Table 2:* Estimated perinatal mortality rates (deaths/1000 total births).**

population level of some of the highest burden districts in Pakistan and reveals both higher mortality rates and substantial sub-district disparities as compared to national average. Our findings suggest that both neonatal mortality and U5 mortality vary within districts themselves with noticeable clustering patterns. These spatial variations within districts are consistent with other findings suggestive of higher mortality risk in some rural populations.[17,18] Nevertheless, predictors identified in our study are generally consistent with those found in other analyses of national and district level data.

Several limitations should also be recognized in the analysis or interpretation of these data. Given limited time available for the baseline assessment, we could not collect information on coverage for all potential interventions and the source of interventions (such as public or private sector), as a separate province specific demographic and health survey was also underway. Other limitations of this study include the retrospective pregnancy history data which may be subject to recall errors, and limited information on location and causes of deaths. Furthermore, there was insufficient information from this baseline survey to identify predictors of mortality such as quality of care and health system functionality. Additionally the population living in the area for less than three months was excluded from the survey and hence we lack information on high-risk migratory populations in the districts. Moreover, the study didn't include children whose mothers had died, who are also likely to be at increased risk of death. The survey was undertaken before the COVID-19 pandemic, however, after the initial stringent measures, there have been no major changes in health service provision and hence we believe that these findings are quite relevant to the present status.

Factors associated with higher mortality include lack of maternal education, higher parity, lack of antenatal care, poorer LHW coverage and residence at a greater distance from the main district hospital. Mothers with more than five years of education reported lower neonatal and U5 mortality rates, consistent with evidence in the literature that health knowledge, attitudes and practices are likely directly associated with maternal education.[19] These are consistent with findings that educated mothers have better care seeking patterns such as more frequent ANC, preparation for delivery in a health facility, and positive care seeking behaviours for child diarrhea and pneumonia as well as higher uptake of scheduled immunizations.[4,20,21] Maternal education may also be associated with improved understanding of danger signs among children, as well as decision making capacity for care seeking.[22]

Previous research has also shown higher mortality rates in rural areas of Pakistan, attributed to a number of causes including larger household sizes in rural areas[23,24] and low coverage of modern family planning methods and health services.[25] The finding of higher mortality rates among children of multiparous women in our survey is also consistent with other findings.[4,26] Distance to district referral hospital was a strong predictor of U5 mortality and could relate to compromised accessibility and socioeconomic conditions in rural areas. Additionally, poor hygiene practices, and differences in breast feeding patterns could be associated with increased risk of respiratory diseases, diarrhea, and other injuries among U5 children.[27,28]

Our results indicate that male neonates had higher mortality compared to females. Probable causes in the literature include male neonates being more vulnerable to infections, congenital abnormalities and immune deficiency.[29] These findings are consistent with other local and regional studies showing comparatively higher neonatal mortality among males, reflecting a biological disadvantage.[4,30] However, this soon reverses and post-neonatal mortality rates are higher among females than males. Social and cultural norms preferences for boys are known to exist in rural areas of Pakistan, which could lead to better health care and attention being paid to boys than girls. Furthermore, while we don't have direct evidence, female infants are known to be at a higher risk of malnutrition due to gender discrimination and low social status.[31,32]

The LHW program in Pakistan is the mainstay of primary health care services in rural areas and provides a link between the community and basic healthcare facilities. LHWs principally focus on health promotion at primary care level and family planning services.[33] Other studies have shown that community-based interventions in Pakistan involving LHWs can contribute to improved neonatal and other childhood health indicators.[7–9] These studies are consistent with other studies in LMICs including India, Bangladesh, Uganda, South Africa, Mexico and the Philippines.[34] However, there are limits to what LHWs and other community health workers can achieve in terms of reducing neonatal mortality in community settings, and the importance of strong referral pathways and quality care in facilities has been

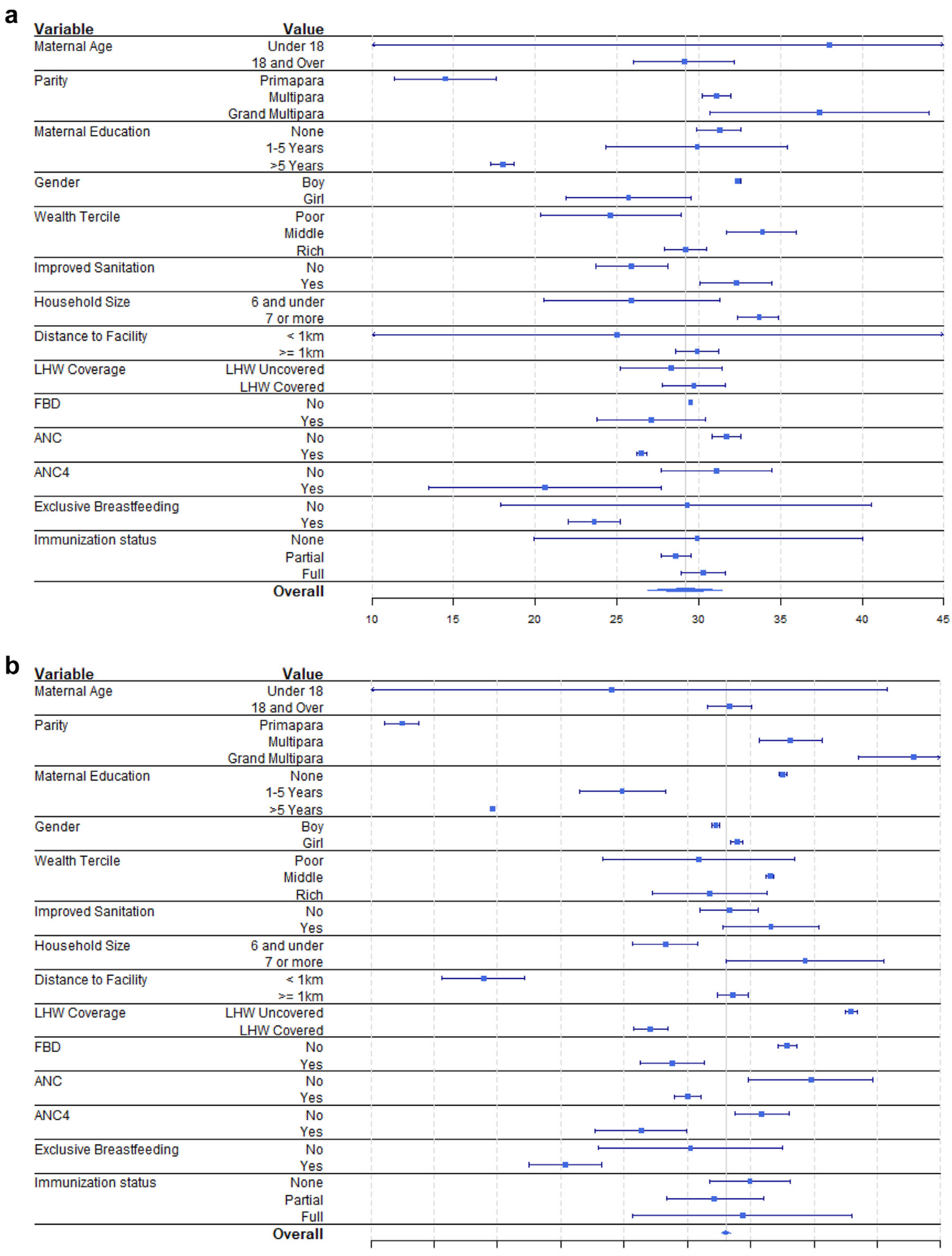

Fig. 2: a) NMR estimates by subgroup (deaths/1000 live births). b) U5MR estimates by subgroup (deaths/1000 live births).

Variable	Unadjusted		Adjusted	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Distal level				
Maternal age				
Under 18	Ref.	0.471		
18 and over	1.54 (0.48–4.94)		na	na
Maternal education				
Secondary+	Ref.	0.006	Ref.	0.053
Primary	1.69 (1.07–2.67)		1.59 (1.00–2.52)	
None	1.77 (1.24–2.51)		1.56 (1.09–2.25)	
Parity				
Primipara	Ref.	<0.0001	Ref.	<0.0001
Multipara	2.35 (1.71–3.24)		2.89 (1.99–4.21)	
Grand multipara	2.84 (2.06–3.91)		3.39 (2.30–5.00)	
Gender				
Male	Ref.	0.008	Ref.	0.006
Female	0.78 (0.66–0.94)		0.77 (0.64–0.93)	
Wealth tercile				
Poor	Ref.	0.015		0.006
Middle	1.39 (1.11–1.74)		1.47 (1.16–1.87)	
Rich	1.18 (0.93–1.49)		1.32 (1.02–1.71)	
Intermediate level				
Distance to facility				
Less than 1 km	Ref.	0.449		
1 km or greater	1.21 (0.74–1.99)		na	na
Household size				
6 and under	Ref.	0.005		
7 or more	1.33 (1.09–1.62)		na	na
Proximal level				
LHW status of household				
LHW covered	Ref.	0.925		
LHW uncovered	0.99 (0.81–1.21)		na	na
Facility based delivery				
Yes	Ref.	0.076		
No	1.19 (0.98–1.45)		na	na
ANC4				
≥4	Ref.	<0.0001	Ref.	0.002
<4	1.55 (1.22–1.98)		1.51 (1.17–1.95)	

Overall p-value reported in parenthesis for multi-category variables. na: Not included in final model (Excluded in model building process).

Table 3: **Results of Cox regression model for neonatal mortality.**

underscored as a key factor in reducing perinatal and neonatal mortality.[35,36]

Our study did not find evidence of a difference in neonatal mortality in the study districts between areas with adequate LHW coverage and those without. Possible reasons for this finding may be infrequent attendance of LHWs during pregnancy, lack of training in newborn survival interventions (such as those for birth asphyxia and preterm care) and low quality of care in primary care settings.[35,36] Other reasons could relate to under utilization of the services for the newborns.[37] Our study did, however, find that LHW coverage was associated with lower risk of child mortality. In addition to supporting the uptake of common childhood vaccines, LHWs do play a major role in screening for danger signs and referring high risk children to the health facilities and maintaining a system for follow up visits until complete recovery.[6] However, we cannot completely exclude the possibility that uncovered areas differed in some systematic way from LHW covered areas including feudal and social systems and the status of women.

In summary, the baseline survey of the UeN project identified a number of opportunities for improving targeting of key interventions to address social determinants of health such as poverty, female literacy and other factors affecting empowerment and autonomy of

Variable	Unadjusted		Adjusted	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Distal level				
Maternal age				
Under 18	Ref.	0.533		
18 and over	1.31 (0.56–3.07)		na	na
Maternal education				
Secondary+	Ref.	<0.0001	Ref.	0.0007
Primary	1.37 (0.91–2.06)		1.10 (0.73–1.66)	
None	2.14 (1.56–2.93)		1.60 (1.15–2.22)	
Parity				
Primipara	Ref.	<0.0001	Ref.	<0.0001
Multipara	3.13 (2.32–4.22)		2.87 (2.13–3.88)	
Grand multipara	3.74 (2.75–5.08)		3.13 (2.29–4.27)	
Gender				
Male	Ref.	0.060	Ref.	0.027
Female	1.15 (0.99–1.33)		1.18 (1.02–1.37)	
Wealth tercile				
Poor	Ref.	0.6332		
Middle	1.05 (0.89–1.24)		na	na
Rich	0.96 (0.81–1.15)		na	na
Intermediate level				
Distance to facility				
Less than 1 km	Ref.	<0.0001	Ref.	0.006
1 km or greater	2.88 (1.75–4.73)		2.06 (1.23–3.46)	
Household size				
6 and under	Ref.	<0.0001		
7 or more	1.38 (1.19–1.62)		na	na
Proximal level				
LHW status of household				
LHW covered	Ref.	<0.0001	Ref.	<0.0001
LHW uncovered	1.65 (1.39–1.96)		1.48 (1.24–1.78)	
Facility based delivery				
Yes	Ref.	<0.0001		
No	1.33 (1.13–1.55)		na	na
ANC4				
≥4	Ref.	0.032		
<4	1.21 (1.02–1.45)		na	na

Overall p-value reported in parenthesis for multi-category variables. na: Not included in final model (Excluded in model building process).

Table 4: **Results of Cox regression model for post neonatal mortality.**

decision-making. There is clearly great potential for scaling up measures to reduce poverty, especially among rural women. This is indeed the focus of the Benazir Income Support Program (BISP) of the Government of Pakistan to provide basic support to women in the poorest households.[38] Other conditionalities, like collaboration with education sectors and existing vertical health programs to support female school enrollment, antenatal care, immunizations, and nutrition can be added in due course. The current LHW program has the potential to link up with the BISP program and reach households at greater risk. There is emerging evidence that a number of factors can be identified that assist in triaging such at-risk children for specific care[39] as well as opportunities to increase referrals and facilitate transfers for those living at some distance from district facilities.

Our population-based survey in several high-risk districts in Southern Pakistan confirmed known predictors of neonatal and post neonatal mortality including maternal illiteracy, high parity and household size and gender. Additionally, antenatal care coverage (at least 4 visits) was specifically associated with lower neonatal mortality only. However, LHW coverage and distance to health facility were also specifically associated with under five mortality. These findings underscore the need for a

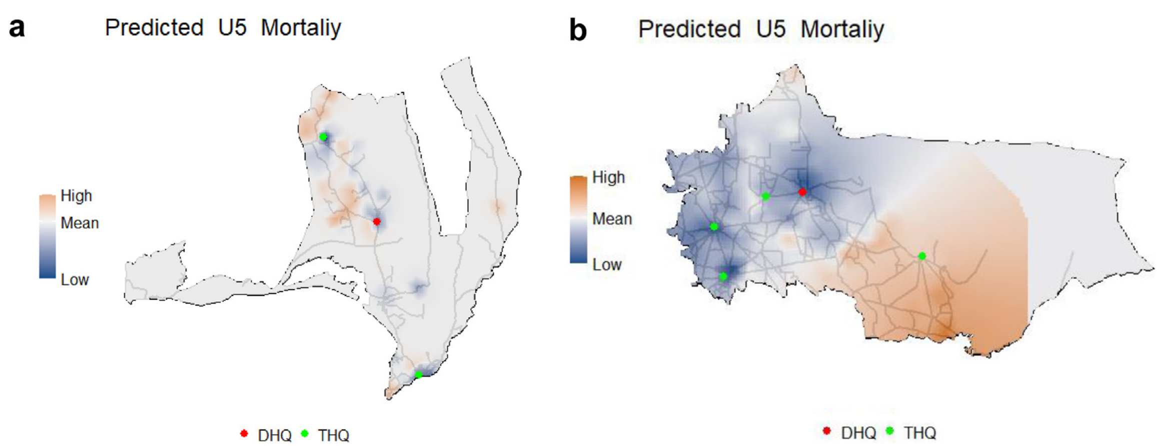

Fig. 3: a) U5MR in Lasbela (Highest). b) U5MR in Sanghar (Lowest).

comprehensive, multisectoral strategy to be implemented for future maternal and child health programs and policies, particularly in rural areas of Pakistan.

Contributors

ZAB led the design of *Umeed e Nau* (UeN) project and provided technical and intellectual inputs as principal investigator in writing the manuscript and approved the final submission. ZM produced the first draft and subsequent drafts of the paper. DF and AR undertook the analysis with inputs from SC, ZAB, ZM. SS, WA, SM, JW, and IA were involved in review and provided inputs on various aspects of the manuscript. All authors reviewed and approved various drafts and the final paper.

Data sharing statement

The project data is available with the Aga Khan University and requests for sharing can be directed to the Principal Investigator (ZAB).

Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Declaration of interests

Primary funding from BMGF was received by the Aga Khan University and subcontract for analysis and support was extended to the Centre for Global Child Health in Toronto. None of the authors received individual funding. All the authors declare no relevant conflicts of interest.

Acknowledgments

We acknowledge the support and collaboration of the household survey respondents. This study would not have been possible, without their participation. The authors are immensely grateful to our research team members who dedicated their time and effort to ensure the smooth execution of this survey. We also sincerely thank the health officials of the Punjab, Sindh, and Balochistan provinces of Pakistan. Their support played a crucial role in the successful execution of this study.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lansea.2023.100231.

References

1 United Nations International Children Education Fund (UNICEF). UNICEF data: monitoring the situation of children and women. https://data.unicef.org/country/pak/; 2020. Accessed March 27, 2020.
2 National Institute of Population Studies (NIPS) [Pakistan], ICF. *Pakistan demographic and health survey 2017-18.* Islamabad, Pakistan, and Rockville, Maryland, USA. 2019.
3 UN Inter-agency Group for child mortality estimation. Child Mortality Estimates. https://childmortality.org/data/Pakistan. Accessed August 17, 2020.
4 Patel K, Rai R, Rai A. Determinants of infant mortality in Pakistan: evidence from Pakistan demographic and health survey 2017–18. *J Public Health*. 2020;29:693–701. https://doi.org/10.1007/s10389-019-01175-0.
5 Bhutta ZA, Hafeez A, Rizvi A, et al. Reproductive, maternal, newborn, and child health in Pakistan: challenges and opportunities. *Lancet*. 2013;381(9884):2207–2218. https://doi.org/10.1016/S0140-6736(12)61999-0.
6 Nisar Y Bin, Dibley MJ. Determinants of neonatal mortality in Pakistan: secondary analysis of Pakistan demographic and health survey 2006-07. *BMC Public Health*. 2014;14:663. https://doi.org/10.1186/1471-2458-14-663.
7 Lawn JE, Blencowe H, Oza S, et al. Every newborn: progress, priorities, and potential beyond survival. *Lancet*. 2014;384(9938):189–205. https://doi.org/10.1016/S0140-6736(14)60496-7.
8 Memon ZA, Khan GN, Soofi SB, Baig IY, Bhutta ZA. Impact of a community-based perinatal and newborn preventive care package on perinatal and neonatal mortality in a remote mountainous district in Northern Pakistan. *BMC Pregnancy Childbirth*. 2015;15:106. https://doi.org/10.1186/s12884-015-0538-8.
9 Rabbani F, Perveen S, Aftab W, Zahidie A, Sangrasi K, Qazi SA. Health workers' perspectives, knowledge and skills regarding community case management of childhood diarrhoea and pneumonia: a qualitative inquiry for an implementation research project "Nigraan" in district Badin, Sindh, Pakistan. *BMC Health Serv Res*. 2016;16(1):462. https://doi.org/10.1186/s12913-016-1699-5.
10 Bhutta ZA, Soofi S, Cousens S, et al. Improvement of perinatal and newborn care in rural Pakistan through community-based strategies: a cluster-randomised effectiveness trial. *Lancet*. 2011;377(9763):403–412. https://doi.org/10.1016/S0140-6736(10)62274-X.
11 Bhutta ZA, Das JK, Bahl R, et al. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet*. 2014;384(9940):347–370.
12 Liu L, Oza S, Hogan D, et al. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the sustainable development goals. *Lancet*. 2016;388(10063):3027–3035.
13 Memon ZA, Mohammad S, Soofi S, et al. Protocol: effect and feasibility of district level scale up of maternal, newborn and child health interventions in Pakistan: a quasi-experimental study. *BMJ Open*. 2020;10(7):e036293.
14 Aziz A, Ali SM. Proximate determinants of fertility in Pakistan [with comments]. *Pakistan Dev Rev*. 1994;33(4):727–742. http://www.jstor.org/stable/41259790.
15 Rutstein SO, Rojas G. *Guide to DHS statistics*, 38:78. Calverton, MD: ORC Macro; 2006. ophi.org.uk.
16 Masset E. SYNCMRATES: Stata module to compute child mortality rates using synthetic cohort probabilities. Statistical Software Components; 2016. econpapers.repec.org

17 Ayele DG, Zewotir TT, Mwambi HG. Structured additive regression models with spatial correlation to estimate under-five mortality risk factors in Ethiopia biostatistics and methods. *BMC Public Health*. 2015;15:268. https://doi.org/10.1186/s12889-015-1602-z.
18 Singh A, Pathak PK, Chauhan RK, Pan W. Infant and child mortality in India in the last two decades: a geospatial analysis. *PLoS One*. 2011;6(11):e26856. https://doi.org/10.1371/journal.pone.0026856.
19 Andriano L, Monden CWS. The causal effect of maternal education on child mortality: evidence from a quasi-experiment in Malawi and Uganda. *Demography*. 2019;56(5):1765–1790. https://doi.org/10.1007/s13524-019-00812-3.
20 Greenaway ES, Leon J, Baker DP. Understanding the association between maternal education and use of health services in Ghana: exploring the role of health knowledge. *J Biosoc Sci*. 2012;44(6):733–747. https://doi.org/10.1017/S0021932012000041.
21 Tekelab T, Chojenta C, Smith R, Loxton D. The impact of antenatal care on neonatal mortality in sub-Saharan Africa: a systematic review and meta-analysis. *PLoS One*. 2019;14(9):e0222566. https://doi.org/10.1371/journal.pone.0222566.
22 Iftikhar ul Husnain M, Rashid M, Shakoor U. Decision-making for birth location among women in Pakistan: evidence from national survey. *BMC Pregnancy Childbirth*. 2018;18(1):226. https://doi.org/10.1186/s12884-018-1844-8.
23 Mugo NS, Mya KS, Raynes-Greenow C. Exploring causal pathways for factors associated with neonatal, infant and under-five mortality, analysis of 2015-2016 Myanmar demographic health survey. *J Glob Health Rep*. 2019;3:2019015. https://doi.org/10.29392/joghr.3.e2019015.
24 Helova A, Hearld KR, Budhwani H. Associates of neonatal, infant and child mortality in the Islamic Republic of Pakistan: a multilevel analysis using the 2012–2013 demographic and health surveys. *Matern Child Health J*. 2017;21(2):367–375. https://doi.org/10.1007/s10995-016-2121-y.
25 Memon ZA, Zaidi S, Riaz A. Residual barriers for utilization of maternal and child health services: community perceptions from rural Pakistan. *Glob J Health Sci*. 2015;8(7):47–57. https://doi.org/10.5539/gjhs.v8n7p47.
26 Akseer N, Kamali M, Bakhache N, et al. Status and drivers of maternal, newborn, child and adolescent health in the Islamic world: a comparative analysis. *Lancet*. 2018;391(10129):1493–1512. https://doi.org/10.1016/S0140-6736(18)30183-1.
27 Chao F, You D, Pedersen J, Hug L, Alkema L. National and regional under-5 mortality rate by economic status for low-income and middle-income countries: a systematic assessment. *Lancet Glob Health*. 2018;6(5):e535–e547. https://doi.org/10.1016/S2214-109X(18)30059-7.
28 Adebowale SA, Morakinyo OM, Ana GR. Housing materials as predictors of under-five mortality in Nigeria: evidence from 2013 demographic and health survey. *BMC Pediatr*. 2017;17(1):30. https://doi.org/10.1186/s12887-016-0742-3.
29 Alonso V, Fuster V, Luna F. Causes of neonatal mortality in Spain (1975-98): influence of sex, rural-urban residence and age at death. *J Biosoc Sci*. 2006;38(4):537–551. https://doi.org/10.1017/S0021932005026957.
30 Hameed N, Abed B. Descriptive study of neonatal death in neonatal care unit of Baghdad Teaching Hospital. *Journal of faculty of Medicine; Baghdad*. 2012;54(3). https://doi.org/10.32007/jfacmedbagdad.v3214-217%.
31 Costa JC, da Silva IC, Victora CG. Gender bias in under-five mortality in low/middle-income countries. *BMJ Glob Health*. 2017;2(2):e000350.
32 Shafiq A, Hussain A, Asif M, Jameel A, Sadiq S, Kanwel S. Determinants of gender disparity in nutritional intake among children in Pakistan: evidence from PDHS. *Children*. 2022;9:7. https://doi.org/10.3390/children9010007.
33 Hafeez A, Mohamud BK, Shiekh MR, Shah SI, Jooma R. Lady health workers programme in Pakistan: challenges, achievements and the way forward. *J Pakistan Med Assoc*. 2011;61(3):210–215. https://ecommons.aku.edu/pakistan_fhs_mc_surg_neurosurg/248/.
34 Gilmore B, McAuliffe E. Effectiveness of community health workers delivering preventive interventions for maternal and child health in low- and middle-income countries: a systematic review. *BMC Public Health*. 2013;13:847. https://doi.org/10.1186/1471-2458-13-847.
35 Soofi S, Cousens S, Turab A, et al. Effect of provision of home-based curative health services by public sector health-care providers on neonatal survival: a community-based cluster-randomised trial in rural Pakistan. *Lancet Glob Health*. 2017;5(8):e796–e806. https://doi.org/10.1016/S2214-109X(17)30248-6.
36 Qureshi RN, Sheikh S, Hoodbhoy Z, et al. Community-level interventions for pre-eclampsia (CLIP) in Pakistan: a cluster randomised controlled trial. *Pregnancy Hypertens*. 2020;22:109–118. https://doi.org/10.1016/j.preghy.2020.07.011.
37 Ayaz A, Saleem S. Neonatal mortality and prevalence of practices for newborn care in a squatter settlement of Karachi, Pakistan: a cross-sectional study. *PLoS One*. 2010;5(11):e13783. https://doi.org/10.1371/journal.pone.0013783.
38 Cheema I, Farhat M, Binci M, Asmat R, Javeed S, O'Leary S. *Benazir income support programme: evaluation report*. 2020. Oxford, UK.
39 Bhutta ZA, Chopra M. The countdown for 2015: what lies ahead? *Lancet*. 2012;380(9848):1125–1127. https://doi.org/10.1016/S0140-6736(12)61382-8.