The measurement of neonatal mortality: How reliable is Demographic and Household Survey Data?

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July 2012

ISSN2042-4116

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Abstract

It is estimated that, on a global scale, neonatal deaths now contribute to nearly 40% of all mortality in children under the age of five. However, as most neonatal deaths occur at home in countries with no vital registration, estimates of mortality are normally based on large national surveys such as the Demographic and Household Surveys (DHS). However, these have major limitations which restrict their accuracy.
This study explores the potential contribution of DHS data in improving knowledge of trends in neonatal mortality in developing countries. It analyses the potential causes and extent of both sampling and non-sampling errors using review of existing literature as well as original analysis.
The study suggests that one of the greatest limitations for DHS data is the wide confidence intervals. This makes it impossible to use DHS data to detect relatively small changes over time. While analysis suggests that in most countries data on neonatal mortality conform to expected patterns, there is also some evidence of age-heaping and back-dating of deaths.

Keywords

Neonatal, demographic surveys, mortality measurement, data quality, data reporting, developing countries

Editorial Note

Dr Sarah Neal is currently an ESRC post-doctoral fellow at the Centre for Global Health, Population, Poverty and Policy (GHP3) at the University of Southampton.

ESRC Centre for Population Change

The Centre for Population Change (CPC) is a joint initiative between the Universities of Southampton, St Andrews, Edinburgh, Stirling, Strathclyde, in partnership with the Office for National Statistics (ONS) and theNational Records of Scotland (NRS). The Centre is funded by the Economic and Social Research Council (ESRC), grant number RES-625-28-0001.

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Acknowledgements

This study was made possible by funding from the Economic and Social Research Council (ESRC).

The author would like to acknowledge the help and advice provided by Professor John Micklewright, Professor Zoe Matthews and Professor Jane Falkingham during the development of this paper. Thanks also to Theresa Mc Gowan for her work in editing and preparing the manuscript for publication.

1. Introduction

While significant progress has been made in reducing mortality in the post-neonatal and early childhood periods within the last few decades, progress in reducing neonatal mortality is less marked[1]. This has resulted in an increasing proportion of deaths in children under the age of five occurring in the first 28 days of life. It is estimated that, on a global scale, neonatal deaths now contribute to nearly 40% of all mortality in children under the age of five (You *et. al*. 2010).

Despite the very high burden of mortality, the problem of neonatal mortality has received little attention until relatively recently. There is now a growing consensus within the international community that increased efforts are needed to reduce newborn deaths if further progress is to be made in reducing child mortality. In most countries the Millennium Development Goal to reduce child mortality by three-quarters by 2015 will not be achieved unless significant progress is made in reducing deaths within the first month of life.

Part of the reason for this past neglect is that neonatal mortality is largely a hidden problem: deaths occur mostly at home, and are not documented in any official records. Ensuring accurate estimates of neonatal mortality can be particularly problematic. This paper initially outlines some of the problems in measuring neonatal mortality in developing countries. It then provides a comprehensive analysis of the quality of Demographic and Household Survey (DHS) data for measuring neonatal mortality. This starts with an examination of non-sampling error, with a particular focus on what is already known from existing data on the problem of possible omissions and age heaping at seven days. It will then present some original analysis to try to ascertain the degree of heaping at one month. No previous studies have

[1] The neonatal mortality rate (NMR) is the number of deaths occurring in live-born infants before the 28th day of life per 1000 live births. The terms "neonate" and "newborn" are often used interchangeably.
Post-neonatal mortality rate (PNMR) is the number of deaths of children between 28 days and one year per thousand live births. DHS calculates this by subtracting NMR from the Infant mortality rate. Infant mortality rate (IMR) is the number of deaths in children before the age of one year per thousand live births. Early childhood mortality rate (ECMR) is the number of deaths in children over 12 months of age but less than five years of age per 1000 children reaching 12 months.

examined this, and it is an important omission as heaping, either at 28 days or one month, could indicate under-reporting of neonatal mortality.

The next section will then examine the internal consistency of neonatal mortality data. While some types of error are difficult to detect, previous studies have shown that neonatal mortality generally conforms to a number of accepted patterns. One relationship that has been previously documented is the correlation between the proportion of child deaths occurring in the neonatal period and the overall under five and infant mortality rate. Because neonatal deaths tend to be the most persistent, as overall child mortality rates decrease the proportion of deaths occurring in the neonatal period increases. The degree to which DHS data conforms to these patterns may provide some (albeit approximate) indication of quality, which is examined here using the data on which this study is based. Further analysis is also carried out to see the ratio of early to late neonatal deaths conforms to expected patterns.

Because DHS collect data on child mortality in five year periods up to 25 years prior to the survey, it offers an opportunity to compare data from different surveys covering the same time period (*i.e.* by using differing periods of time prior to data collections for surveys from the same country but different years) as a further method for evaluating accuracy. Curtis (1995) carried out this comparison for a relatively small number of DHS surveys, but this study offers more extensive opportunities for analysis.

The paper then outlines some of the sampling errors inherent in the DHS data with regards to neonatal mortality rate (NMR) estimates, before concluding with a discussion on the extent to which DHS data can be used to analyse trends over time.

2. The measurement of neonatal mortality in developing countries

The accurate measurement of neonatal mortality in developing countries presents a number of challenges, and limited data has probably contributed to the lack of focus given to this area in the past (Lawn *et al* 2001) . In most developing countries vital registration is incomplete or non-existent, and since many neonatal deaths occur

within the home without any contact with medical services they are not recorded by health information systems. Even where institutional delivery is common, varying policies for classification of neonatal deaths and stillbirths can result in measurement discrepancies (Aleshina and Redmond 2005). There is also some evidence that within certain health systems there are incentives for staff to misreport neonatal deaths as stillbirths in order to avoid audit or improve hospital ratings when NMR is used as an indicator of quality (ibid.).

The development of effective and comprehensive vital registration systems are unlikely to be achieved in the near future by many countries. There are currently almost no countries with both child mortality rates of over 25 per 1000 live births and complete coverage of vital registration (classified as 95% of all deaths recorded) (Morris *et al* 2003). The development of ongoing retrospective surveys or sample registration systems, such as those developed in China and India, are another option. The Indian Sample Registration Survey (SRS) actually uses dual methods to gather data: births and deaths are continuously enumerated in a sample of areas by a part-time worker and six monthly retrospective studies are also carried out. However, it would appear that even the dual methods used by the SRS produce underestimations of mortality (Bhatt 2002).

3. Demographic and Household Surveys (DHS)

The only feasible method of collecting reliable national-level direct estimates on neonatal death rates in many developing countries is through large surveys such as the DHS. These are nationally representative surveys with sample sizes of usually about 5,000-20,000 households providing data on a wide range of indicators in the areas of population, health and nutrition. Full birth histories are collected from women aged 15-49 years in sampled households, and data is comparable both over time and between countries. The women are asked a series of questions about each birth they have experienced, including month and year of the infant's birth, and, if no longer living, age at death (in days if under a month old). Children who were born or died during the month prior to the interview are excluded. Mortality estimates are calculated according to the conventional life table approach. Deaths and exposure in

any calendar period are first tabulated by age intervals in months of 0, 1-2, 3-5, 6-11, 12-23, 24-35, 36-47 and 48-59. Age-interval-specific probabilities of survival are then calculated, and probabilities for larger age segments are calculated by multiplying the relevant age interval survival probabilities together and subtracting the result from one (Rutstein 1983).

4. The data and analysis

The data used for the analyses in this study is taken from 57 DHS carried out between 1990 and 2002. Thirty of these were in Sub-Saharan Africa, eight in South and South East Asia, six were in North Africa and Western Asia, nine in Latin America and the Caribbean and four in Central Asia.

4.1 Non-sampling error in DHS data

Omissions of deaths

Even a relatively large scale survey of this type may experience a number of potential problems that compromise the accuracy of the data collected. Probably the greatest risk from non-sampling errors is omission of child deaths, which is a problem thought to be most prevalent in the neonatal period (Curtis 1995). Although mothers are asked to recall all infants born alive who later died,[2] neonatal deaths may be misclassified as stillbirths, either in genuine error or because of cultural beliefs and practices. The problem is compounded by very limited DHS data on stillbirths, so it is not possible to jointly review trends in the two rates in order to provide a more comprehensive picture. There is some evidence from earlier World Fertility Survey (WFS) data that these omitted deaths are concentrated amongst the most socially and economically disadvantaged (Hobcraft *et al* 1984), which may result in the introduction of important biases.

While it is difficult to estimate the degree of under-reporting, a study in the Indian state of Maharashtra (Bang *et al* 2002) found an NMR nearly 20 points higher (51.2

[2] The interviewers also use a probe which asks whether the mother had "any baby who cried or showed signs of life but did not survive", DHS 2003),

deaths per 1000 as opposed to 32 deaths per 1000) than that recorded in the 1998 Indian National Family and Household Survey for this state (NFHS, a DHS equivalent). However Bang *et al* (2002) acknowledge that at least some of this difference may be explained by selection bias in the study population, which contained a much higher proportion of tribal people than the NFHS survey (ibid.). In addition Hill and Choi (2006) suggest that further error could have been introduced by paying informants to report deaths. They also point out that the ratios of neonatal to infant deaths are similar in both the study and NFHS data. While this in no way demonstrates that the NFHS did not under-report neonatal deaths, it does indicate that NMR is not differentially under-reported when compared to post-neonatal mortality.

Data heaping

A further potential problem is that of data "heaping", *i.e.* the preference for reporting deaths at a particular day, week or month. Hill and Choi (2006) carried out some analysis to establish the degree to which heaping occurs at seven days and found that, in 40% of the DHS surveys they examined, one half or more of all deaths occurring between four and nine days were reported at seven days. This could be important as it means that a number of deaths occurring in the early neonatal period will actually be recorded as late neonatal deaths, but it is of little relevance in studies that do not seek to differentiate between early and late deaths. The possibility of heaping at 28/30 days or one month is of much more importance as this would lead to under-reporting of neonatal deaths. There appears to be a very small amount of heaping at 30 days in all regions (and also at 28 and 31 days in some regions) which might lead to slight underestimations of NMR, but for most regions this would be negligible (see Appendix 1 for graphs showing reporting of deaths by day for each region).

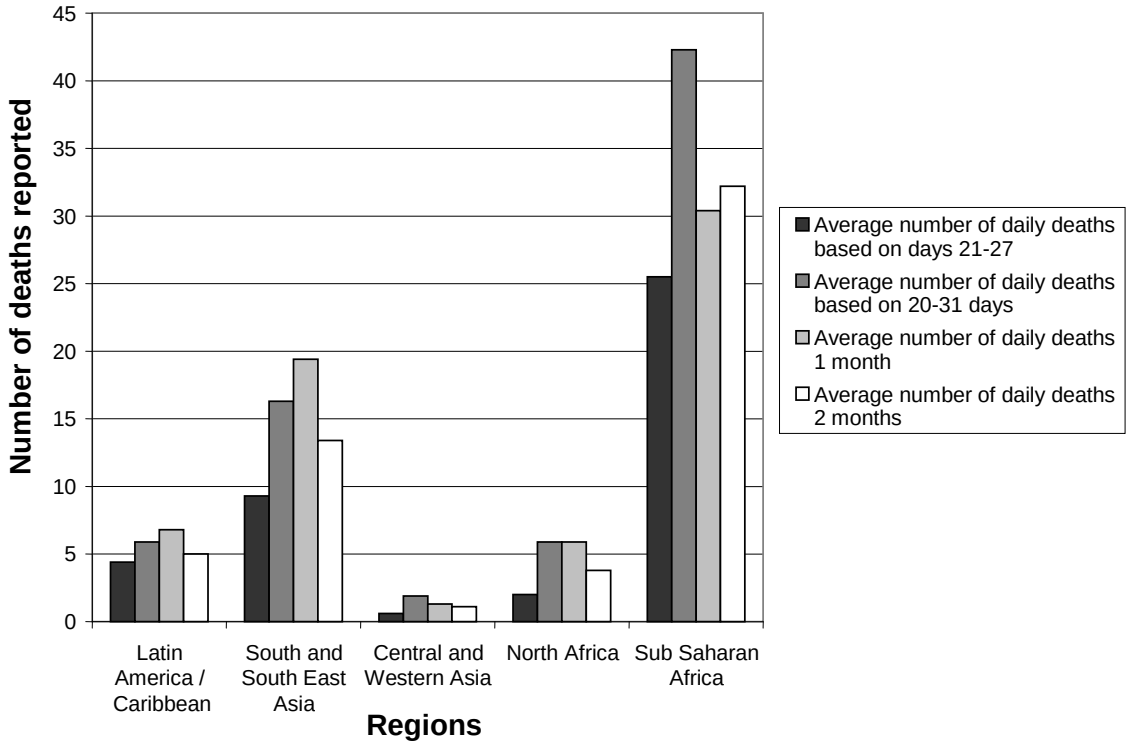
Unfortunately, it is more difficult to ascertain whether some late neonatal deaths are being misreported at one month of age as, after 31 days, the age of death is recorded by month only, and no previous studies have attempted to examine this issue. It could be hypothesised that if large numbers of neonatal deaths were displaced into the one month age group it would be expected that this would affect the pattern of mortality for 1-12 months. This is difficult to verify: while a model has been established of expected distribution of mortality by month (Bourgeois-Pichat 1952, cited in Galley

and Woods, 1999), more recent work has found the pattern to vary considerably between time and place, and there is no single fixed relationship (Galley and Woods 1999). It is therefore not possible to compare DHS infant mortality data distributed by month of death with a model to ascertain with any certainty whether deaths at one month appear overrepresented.

While no model is available, it can certainly be assumed that as infant deaths become less frequent with increasing age, the number of deaths at one month should be markedly less than in deaths occurring in the first 28 days of life. Appendix 2 shows infant mortality bar graphs for the five regions by month of death. In all regions the numbers of deaths recorded at one month are only a fraction of those recorded for less than one month: the percentage ranges from 9% in Sub-Saharan Africa to 17% in Latin America and the Caribbean. There is also no evidence that reported mortality in month one is markedly higher than in months two and three. Even if it were assumed that the number of deaths at one month should be no greater than the number of deaths in months two and three (which may well be an underestimation as infant mortality usually decreases with increasing age) the reassignment of estimated excess deaths would only lead to an increase in deaths before one month of less than 7% for North Africa and Central Asia, Latin America and the Caribbean and South and South East Asia. In Sub-Saharan Africa and Central Asia the number of deaths recorded at one month is actually lower than the two subsequent months. This analysis would suggest heaping is not a major problem.

However, neonatal mortality is extremely high in the first week, and then falls sharply. Probably a better way of comparing neonatal mortality with rates in months one and two is not to look at overall deaths in the first month of life, but rates at the end of the neonatal period. It could be assumed that the average daily number of deaths recorded by surveys for infants one and two months old should be less (or at least the same as) the average daily number of deaths in the later part of the neonatal period. Figure 1 shows the average daily number of deaths for each region reported from 21-27 days (the last week of the neonatal period), compared with average daily figures for one and two months (calculated on a 30 day month).

Figure 1: Average number of daily deaths based on estimates on two different time periods in the first, second and third months of life



Source: Data is from DHS surveys 1990-2002.

Daily rates of mortality in the later neonatal period will vary greatly depending on the period chosen because of heaping of data. Daily average rates have therefore been calculated for two time periods: the "true" final week of the neonatal period from 21-27 days, and a longer period (20-31 days), which strictly speaking exceeds the neonatal period, but includes heaped deaths at 20 days (as well as more modest heaping at 28 and 30 days). It can be seen that all regions have a lower number of daily average deaths recorded in the surveys in the last week of the "true" neonatal period than for one month. The second column shows the daily average calculated from 20-31 days. Even using this estimate, South and South East Asia and Latin America and the Caribbean still have a higher recorded number of average daily deaths at one month (though I do not test to see if these differences are statistically significant), suggesting that some deaths that should have been recorded as occurring before one month may have been displaced. It is impossible to draw any firm conclusions from this very cursory analysis and SEs may be large. However, as the probable actual daily number of deaths occurring in the later part of the first month of life probably lies somewhere between these two estimates displacement may be a

problem in some surveys, causing NMR to be under-reported. Further, more detailed analysis would be worthwhile in order to develop stronger evidence on this issue as this is obviously a potentially major error in the data.

4.2 Internal consistency in DHS data

Correlation between proportion of child deaths occurring in the neonatal period and overall under five and infant mortality

As previously discussed, one way of examining the potential accuracy of DHS neonatal mortality rates is to see whether there is a negative correlation between the proportion of deaths occurring in the neonatal period and the overall child mortality rate. A number of studies, including Hill and Pande (1997) have demonstrated that, as child mortality falls, the proportion of deaths occurring in the neonatal period rises. If the proportion of neonatal deaths is lower than expected, this could suggest omission of deaths.

In order to examine these patterns for the study data, the relationship between overall child mortality and NMR is explored using scatterplots, which provide a visual representation of the relationship between two continuous variables, and Ordinary Least Squares (OLS) regression. OLS is used because the dependent variable (proportion of child deaths in the neonatal period) is continuous. Dummy variables were also added to the OLS regressions to investigate the effect of different regions on proportion of deaths in the neonatal period. This gives the equation:

$$Y = a + B_1 X_1 + B_2 X_2 + e$$

when:

Y = proportion of under five deaths occurring in neonatal mortality;

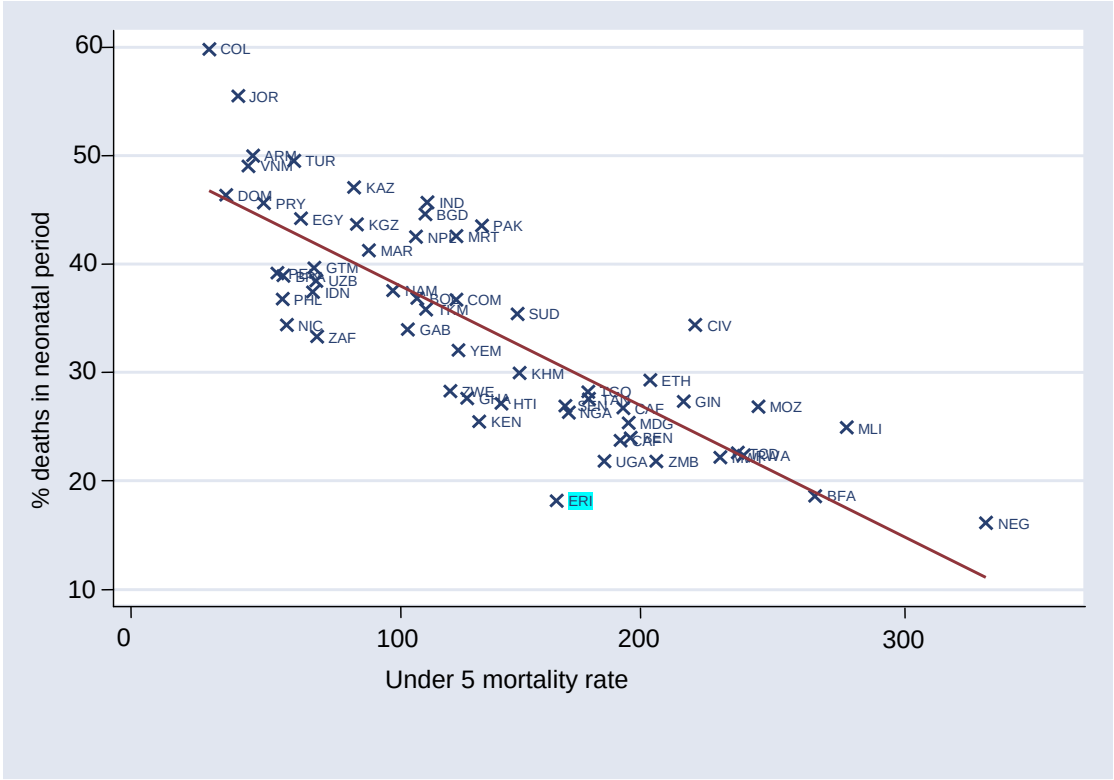
a = constant

X_1 = Overall U5MR; X_2 = Region (dummy); e = error

The scattergram in Figure 2 shows the relationship between the percentage of child deaths occurring within the neonatal period and overall child mortality rates. It broadly concurs with previous well-documented evidence that the proportion of under five mortality in the neonatal period increases as under five mortality decreases. A

few countries, *e.g.* Eritrea (ERI, highlighted) appear to have a lower proportion than may be expected which may indicate under-reporting of neonatal deaths. An OLS regression using percentage of under five deaths occurring in the neonatal period as the dependent variables and under five mortality rate as the independent variable with dummy variables added for region produces the results in Table 1.

Figure 2: Scatterplot showing percentage of deaths in children under five years occurring in the neonatal age group with under 5 mortality rate



* Percentage of all deaths in children under 5 occurring in the neonatal period
Source: Data is from DHS surveys 1990-2002
Note: International Organisation for Standardisation country name abbreviations have been used, and can be found at http://www.un.org/Depts/Cartographic/english/geoinfo/geoname.pdf

Table 1: Results of OLS regression using U5MR and region as independent variables and % of under 5 deaths occurring in the neonatal period as dependent variable

	Unstandardised coefficients	
	B	**Std. Error**
(Constant)	49.8	2.41
Under 5 mortality rate	-0.11**	0.019
North Africa/Western Asia	2.08	2.76
Central Asia	0.01	2.89
Latin America/Caribbean	-2.8	2.61
Sub-Saharan Africa	-6.25**	2.43

*significant at 5% level ** significant at 1% level
57 observations. Adjusted $r^2 = 0.71$ Reference category is South and South East Asia.

The results in Table 1 imply that Sub-Saharan Africa has a percentage of child deaths occurring in the neonatal period approximately six percentage points lower than South and South East Asia (the reference category) when adjusted for under five mortality rate (though the confidence interval is quite wide). Other regions do not vary significantly from the reference category. If the natural log of both the NMR and under 5 mortality rate (U5MR) are used, the adjusted r^2 is increases to 0.82 as the data is non-linear.

There is also a strong correlation between infant and neonatal mortality rates ($r^2 = 0.80$) and this association increases further if the natural log of both IMR and NMR is used ($r^2 = 0.86$). An OLS regression using the natural log of NMR as the dependent variable and natural log of IMR and dummy variables for region as the independent variables produce the results found in Table 2:

Table 2: Results of OLS regression using natural log of IMR and region as independent variables and natural log NMR as dependent variable

	Unstandardised coefficients	
	B	**Std. Error**
(Constant)	0.41	0.24
Log of IMR	0.75**	0.06
North Africa/Western Asia	-0.04	0.07
Central Asia	0.09	0.07
Latin America/Caribbean	-0.14*	0.06
Sub-Saharan Africa	-0.08	0.07

*significant at 5% level ** significant at 1% level
57 observations. Adjusted $r^2 = 0.86$ Reference category is South and South East Asia.

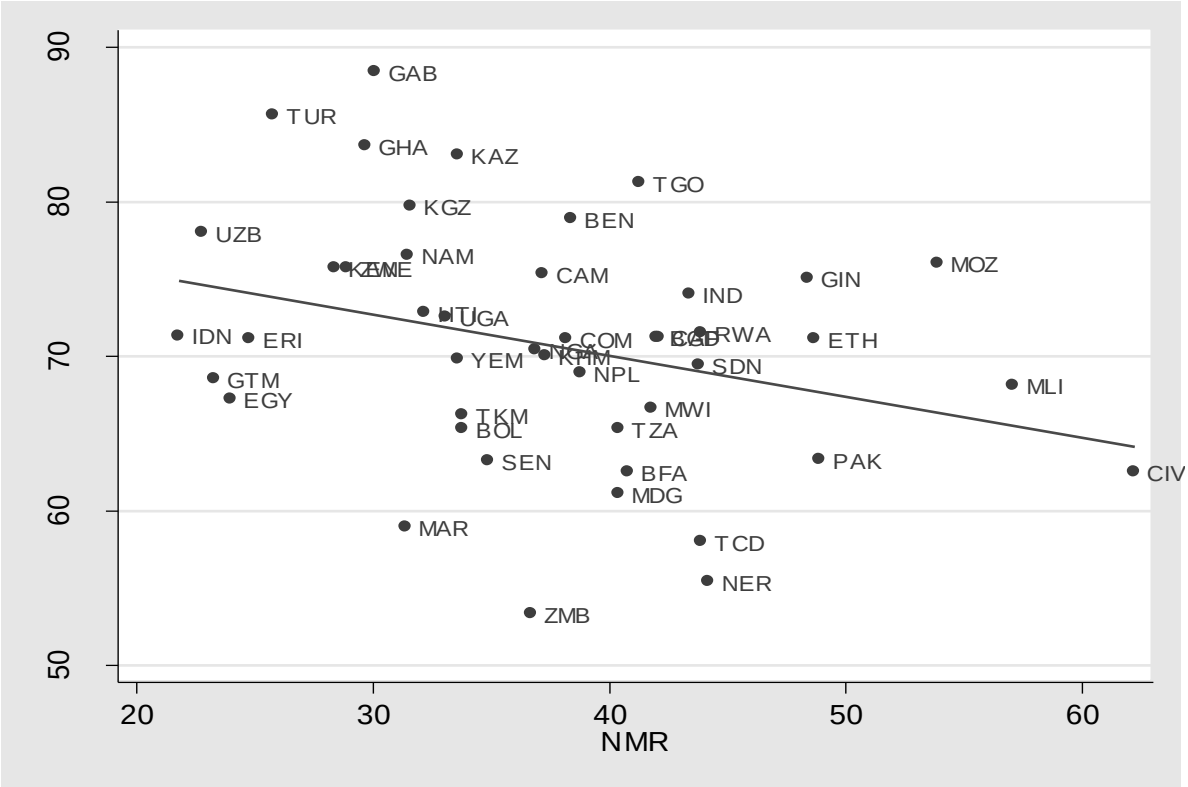
This implies that for every 10% decrease in IMR, NMR will on average decrease by about 7.5%. Latin America and the Caribbean have a significantly lower rate of NMR to IMR from the reference category (South and South East Asia).

The Proportion of early to late neonatal deaths

Boerma (1988, cited in Curtis 1995) suggested that at an NMR of 20 per 1000 or more, approximately 70% of neonatal deaths occur in the first six days, and an unexpected low proportion of early neonatal deaths could be a result of under-reporting deaths in this age group. This would be expected as deaths in the later neonatal period tend to decline earlier than those in the first week of life (Curtis 1995). Hill and Choi (2006) plotted the ratio of early to late NMR in 108 DHS against IMR and compared them with a reference line developed using data from England and Wales 1905-1997[3]. They found that data points for Asia, North Africa and Latin America and the Caribbean were broadly scattered around the historic reference line. In Sub-Saharan African countries there was a higher rate of early than late neonatal deaths than within the model, and there was no apparent relationship with IMR changes. Hill and Choi concluded from this that there is no evidence for substantial omission of early neonatal deaths, but the lack of pattern in some parts of Sub-Saharan Africa may be explained by a high degree of random error in the reporting of age of death in days.

[3] It is worth noting that Hill and Choi smoothed their data to account for the high levels of heaping at seven days before carrying out their analysis.

Figure 3: Scattergram showing percentage of neonatal deaths occurring in the early neonatal period against overall neonatal mortality (with regression line)

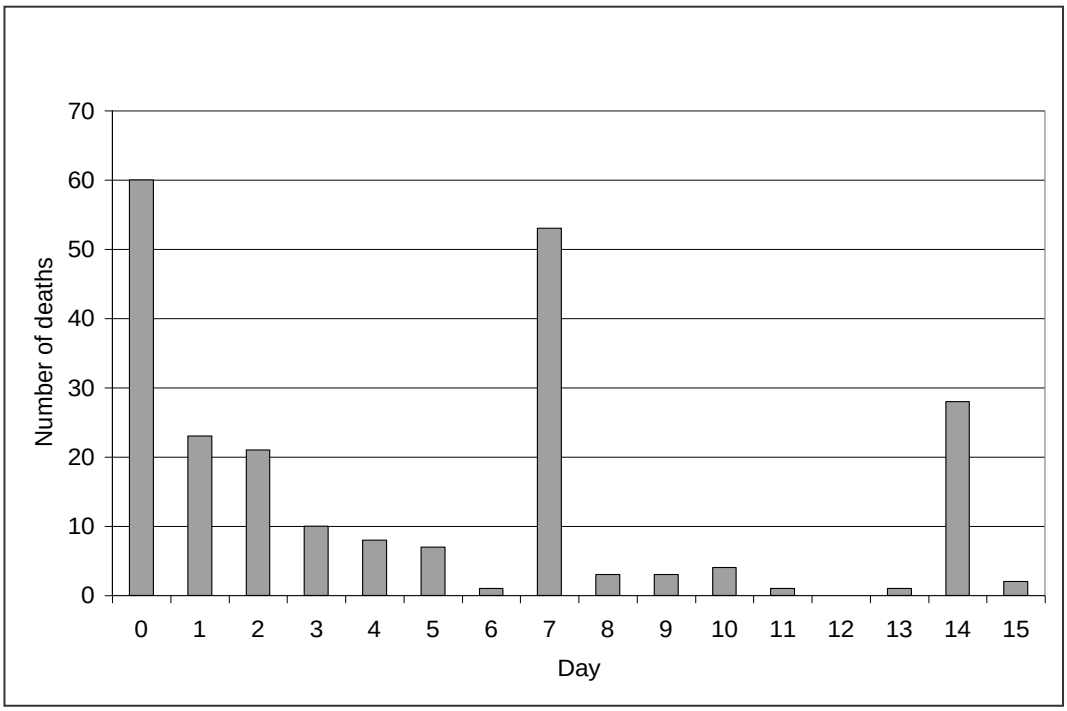


*Percentage of all neonatal deaths occurring between 0-6 days.
Data is from DHS surveys 1990-2002.
Note: International Organisation for Standardisation country name abbreviations have been used, and can be found at http://www.un.org/Depts/Cartographic/english/geoinfo/geoname.pdf

In order to examine the relationship between early and late neonatal mortality for the data used in this study, I created a scattergram of percentage early neonatal mortality plotted against neonatal mortality rate for 46 countries with NMR estimates of 20 or more (Figure 3). The scattergram shows a negative correlation (r^2 = -0.31) between overall neonatal mortality and proportion of deaths occurring in the early neonatal period. The mean proportion of deaths occurring in the first week in the 46 countries with an NMR of 20 or above was 71.1, which would fit with Boerma's analysis. However, this masks significant variation between countries, and the range for percentage of neonatal deaths occurring in the early period ranged from 53.3% to 88.2%. Niger, Chad, Zambia and Morocco (NER, TCD, ZMB, MAR) appear to have levels of early neonatal deaths lower than may be expected. However, a closer examination of the mortality data by day of death suggests it is likely to be as a result of age heaping as described by Hill and Choi (2006). All four countries show marked heaping at day seven, which will result in a higher proportion of deaths recorded in

the late neonatal period. This pattern is particularly striking in Zambia, as illustrated in Figure 4.

Figure 4: Distribution of deaths from 0-14 days by day of death: Zambia DHS 2001/2



A number of other countries such as Gabon, Ghana, Togo, Kazakhstan and Turkey (GAB, GHA, TOG, KAZ, TUR) have higher rates of early neonatal deaths than might be expected. This could be a real reflection of local epidemiological conditions or may result from poor differentiation between early and late neonatal deaths. Alternatively it could indicate either a tendency for stillbirths to be reported as neonatal deaths (resulting in an overestimation of early neonatal deaths) or late neonatal deaths being misclassified as post-neonatal deaths (resulting in an underestimation of late neonatal deaths). However the percentage in the majority of countries falls between about 60% and 80%, suggesting there is no evidence of widespread under-reporting of early neonatal deaths.

Comparison of recall data from 5-9 years with 0-4 year recall from earlier surveys in corresponding time period

Opportunities for external validation of the DHS data are extremely limited as few other comparable direct estimates of national neonatal mortality exist. However, as each survey records data on deaths up to 25 years before the date of the survey divided into five-year time periods, data can be compared from different surveys covering the same time period.

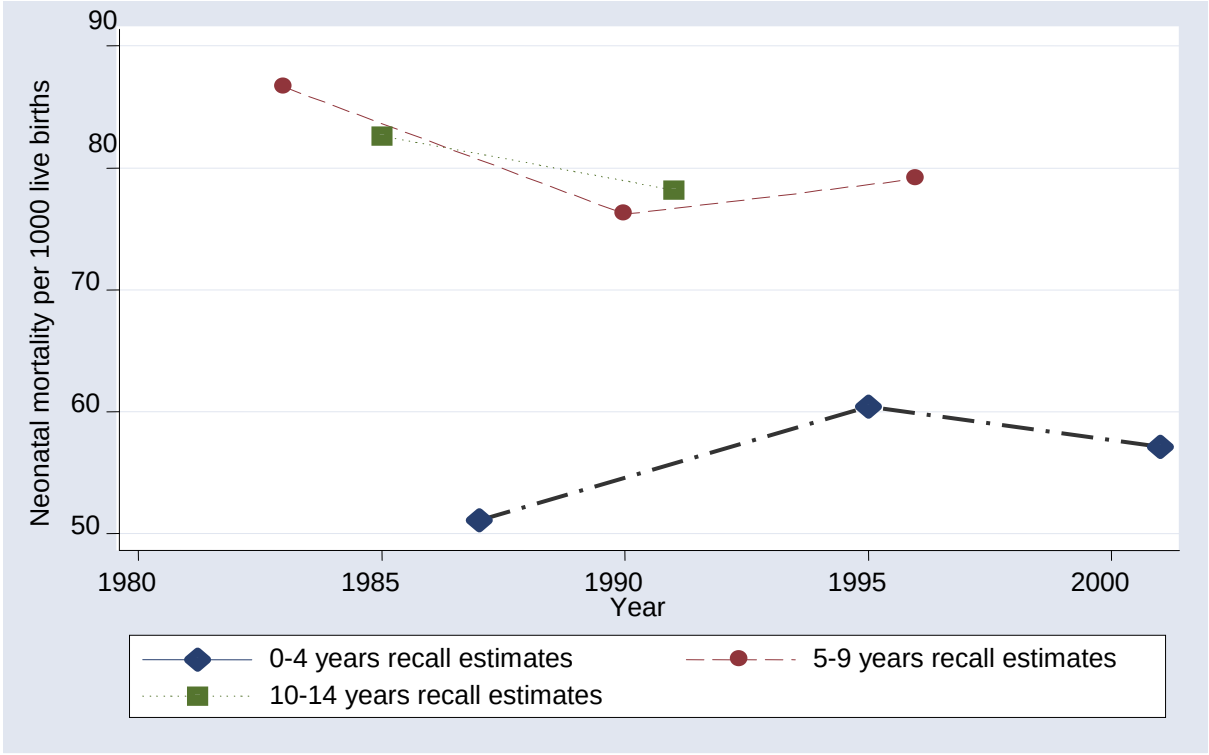
Table 4 shows 5-9 year recall data from the most recent surveys (1990-2002) from 18 countries, along with 0-4 year recall data from preceding surveys undertaken exactly five years previously, and therefore covering a corresponding period. The difference between the two rates is also given.

Table 4: Comparison of recall data from 5-9 years prior to most recent national studies and data from 0-4 years recall from earlier surveys in corresponding time period

Country	Year of first survey	Year of second survey	Recall data from 5-9 years prior to second survey	Data from 0-4 years from earlier survey in correspond-ing time period	Actual difference in rates (0-4 year recall estimate minus 5-9 year recall estimate)	% difference in rates (actual difference as % of 0-4 year recall estimates)
Morocco	1987	1992	36.5	41.5	5.0	12.0
Egypt	1995	2000	34.0	30.4	-3.6	-11.8
Turkey	1993	1998	30.1	29.2	-0.9	-3.1
Yemen	1991/2	1997	47.8	40.9	-6.9	-17.0
Nepal	1996	2001	56.5	49.9	-6.6	-13.2
Philippines	1993	1998	20.7	17.7	-3.0	-16.9
Colombia	1995	2000	17.8	18.7	0.9	4.8
Haiti	1994/5	2000	39.9	31.2	-8.7	-27.9
Benin	1996	2001	44.7	38.2	-6.5	-17.0
Cote d'Ivoire	1994	1998/9	48.7	42	-6.7	-16.0
Ghana	1993	1998	35.1	40.9	5.8	14.2
Kenya	1993	1998	25.5	25.7	0.2	0.7
Madagascar	1992	1997	40.7	39.2	-1.5	-3.8
Mali	1995/6	2001	79.3	60.4	-18.9	-31.3
Senegal	1992/3	1997	38.5	34.9	-3.6	-10.3
Uganda	1995	2000/1	37.1	27	-10.1	-37.4
Zambia	1996	2001/2	29.4	35.4	6.0	16.9
Zimbabwe	1994	1999	23.3	24.4	1.1	4.5

The relatively large standard errors in NMR make comparisons somewhat difficult: assuming the standard errors are similar for DHS data series across time, sampling error could probably not be ruled out as an explanation of differences in any of the countries. However, particular observed patterns suggest that this is not the full explanation for some of the larger differences. The rates recorded in the 5-9 year recall period are higher than those from the 0-4 year period of the earlier study for 12 out of 18 countries (see Figure 5 for the difference in trends based on 0-4, 5-9 and 10-14 year recall data in Mali). This pattern is particularly marked for countries with marked differences in rate: only one of the eight countries with a difference in rates over 15% has a larger estimate from 0-4 year than 5-9 year recall data. The opposite may have been expected, as it has been suggested that event omission is more common when the deaths occurred further back in time, which would lead to lower estimates for the 5-9 year recall period (Curtis 1995). A probable explanation for the observed pattern of higher estimates for 5-9 year recall is the phenomenon of displacing births in time in order for interviewers to avoid asking the extensive series of questions required for children born within five years of the survey. Arnold and Blanc (1990) found strong evidence of this occurrence in Sub-Saharan Africa, which could lead to underestimation of mortality rates. This is very concerning as it suggests that rates of neonatal mortality in these countries may be even higher than current estimates. It also raises doubts about the reliability of using recall data from different periods to establish trends when more than one survey is not available.

Figure 5: Data from DHS surveys 1987, 1995/6 and 2001 in Mali, showing difference in NMR trends based on estimates from 0-4 year, 5-9 year and 10-14 year recall



4.3 Sampling error

Confidence intervals

Sampling error is also a problem leading to confidence intervals that are often quite wide. Standard errors for NMR are usually relatively high compared to those for infant or child mortality as the actual number of deaths are lower (Curtis 1995), and in surveys with low neonatal mortality rates and relatively small sample sizes, the standard errors can be very high. A study by Korenromp *et al* (2004) assessed whether DHS from Sub-Saharan African countries were suitable for establishing whether the Millennium Development Goals for the reduction of child mortality were being met. The median relative standard error[4] for national mortality rates was 4.4% for all under-five mortality, and 5.6% for infant mortality (relative SEs were not calculated for neonatal mortality). They established that for all under-five deaths the DHS from Sub-Saharan Africa could effectively detect changes of 15% or more between subsequent surveys: any smaller changes could be the result of standard error. However, this will obviously be greater for neonatal mortality.

[4] The relative standard error of an estimate is obtained by dividing the standard error of the estimate by the estimate itself. This quantity is expressed as a percentage of the estimate.

Appendix 3 shows the NMR and estimations of standard error for 17 DHS II Surveys as reported by Curtis (1995). The relative standard errors are particularly large for some of the countries in Latin America, where NMR and numbers of births recorded by the survey are relatively low. For example, the 95% confidence intervals for the Dominican Republic (estimated NMR 23.7 per 1000 live births) from 16.3-31.2. In some cases, the relative standard errors for neonatal mortality are more than twice that found for the U5MR: For Burkina Faso and Zambia the relative standard errors for under five mortality rates are 0.033 and 0.036, whereas for NMR they are 0.081 and 0.068 respectively (Curtis 1995). This raises real issues about the accuracy of estimating rates of change or comparisons between countries from DHS data, and relatively small observed changes over time could actually be the result of sampling error rather than real progress.

In addition sampling error makes comparisons of NMR between sub-samples extremely difficult as standard errors will be further increased within the subgroups and only very large differences will be statistically significant.

Sampling bias

Sampling bias will be an issue if certain sectors of the population are under-represented in the survey. A potential cause of bias is that DHS use women of reproductive age as the basic sampling unit, so children without living mothers are excluded from the survey. Studies in resource-poor countries suggest that death of the mother commonly results in death of the child, and this risk is particularly strong for the newborn. A study of maternal mortality in the Jamalpur district of Bangladesh found that of the 21 babies live-born to women who subsequently died, all were dead by 28 days (Khan *et al* 1986). Another larger study also in Bangladesh (Matlab district) showed less dramatic results, but still found that only 65% of infants born alive to mothers who died survived until one month, compared with 94.4% who survived in the control group of infants with living mothers (Koenig *et al* 1988)[5]. This link may lead to an under-reporting of newborn deaths, particularly in countries where maternal mortality is high. A study by Artzrouni and Zaba (2003 cited in Mahy

[5] The differences in these studies may at least be partly due to variation in overall NMR between the two study areas.

2003a) which examined the bias produced by AIDS when using direct estimation techniques for child mortality suggests that while there is likelihood of under-reporting, it is only of a magnitude of 5-7% at most. However, further work would be useful to ascertain if there is any specific bias in NMR data caused by maternal death, and particularly whether estimates in countries that have extremely high all-cause maternal mortality may be more severely affected.

6. Conclusion: How reliable are DHS estimates for neonatal mortality?

While DHS estimates of neonatal mortality are subject to a number of both sampling and non-sampling errors, they are, for many countries, the only viable source of direct estimation of NMR. There is little evidence that inaccuracies are widespread or severe enough to render the data of no value, though sampling and non-sampling errors suggest they are most appropriate for identifying general trends rather than detailed information on specific countries, or family-level analysis of determinants.

Accuracy of estimated neonatal mortality rates from the DHS, particularly in the absence of other national level surveys to provide external validation, are difficult to determine with any certainty. Probably one of the greatest limitations of the DHS data is the wide confidence intervals. This makes it difficult to use DHS data to detect relatively small changes over time, and means that any estimation of rate of change or comparison between countries needs to be interpreted with caution. One possible way of reducing confidence intervals for DHS would be to increase the sample size, and in recent years surveys from the more recent series have markedly larger samples. However, this would have serious financial and practical considerations, and increasing sample size to a degree which would significantly reduce standard errors is probably unlikely. Korenromp *et al* (2004) suggest that one possible solution would be to have an additional shortened survey identifying child mortality, which could be administered to a greater number of clusters.

There is some evidence that a proportion of neonatal deaths may be omitted in some countries. Probably the two most concerning non-sampling errors identified are possible back-dating of deaths which lead to underestimation of deaths, and possible

age heaping at one month (though further analysis of this potential problem is required). Both of these problems could at least partially be reduced by improved training and supervision of survey staff. In recent years interviewers have been trained to probe for the child's exact age at death if the death occurs at one year to avoid heaping at this age (Mahy 2003), and a similar approach could be used to reduce heaping of deaths reported at seven days or one month.

Analysis of change in the proportion of deaths occurring at one day produced ambiguous results. In general countries that had experienced a marked fall in mortality did experience the expected increase in proportion of mortality on day one. However, the findings for Sub-Saharan Africa were more conflicting. This may be because the changes in rate were too small to be reflected in corresponding changes in proportion, or reflect data inaccuracies. However, it must be remembered that the causes underlying the increases in mortality in many countries within this region are not fully explained, and patterns may not be conforming to what is expected: *i.e.* a higher proportion of the excess deaths could be occurring in the very early neonatal period. More analysis should be carried out on this before it is used as a tool for verifying change.

In the medium term it may also be necessary to rely on process indicators for monitoring short-term changes brought about through national programmes. Calculations of these rates from survey data have much greater levels of precision than relatively "rare" events such as child deaths. A number of indicators have been identified, including antenatal attendance, skilled attendance at delivery, tetanus toxoid vaccination, postnatal care and breastfeeding rates. While all these interventions or packages of intervention have strong evidence of impact on neonatal mortality, further research is needed to quantify the level of potential impact of some of these in practice, and how this will vary in different settings and scenarios.

Appendix 1: Bar graphs of distribution of neonatal mortality 0-31 days by day of reported death

Figure 1 (a-e) Distribution of neonatal mortality 0-31 days by day of reported death

Figure a: Sub-Saharan Africa (data from 30 surveys)

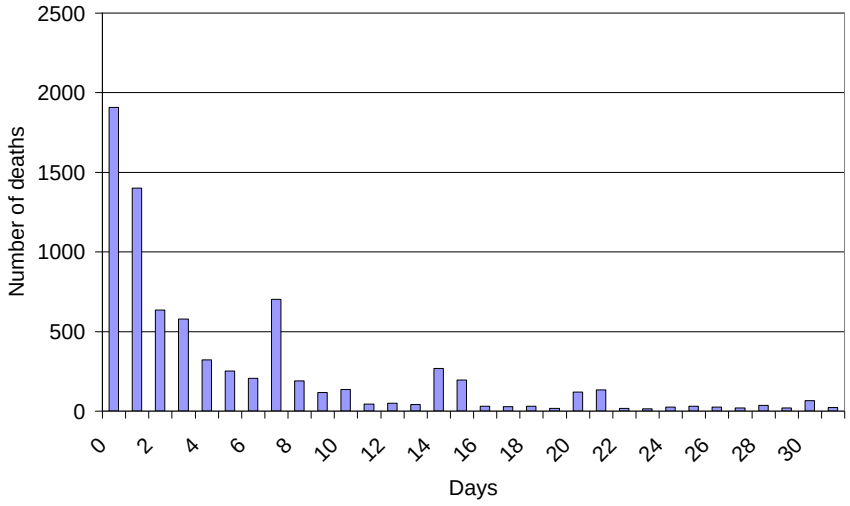


Figure b: South and South East Asia (data from 8 Surveys)

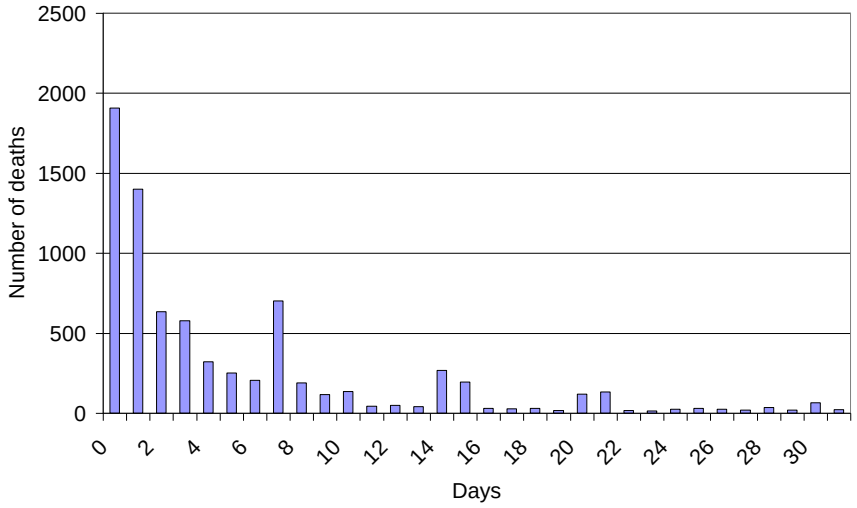


Figure c: North Africa and Western Asia (data from 6 surveys)

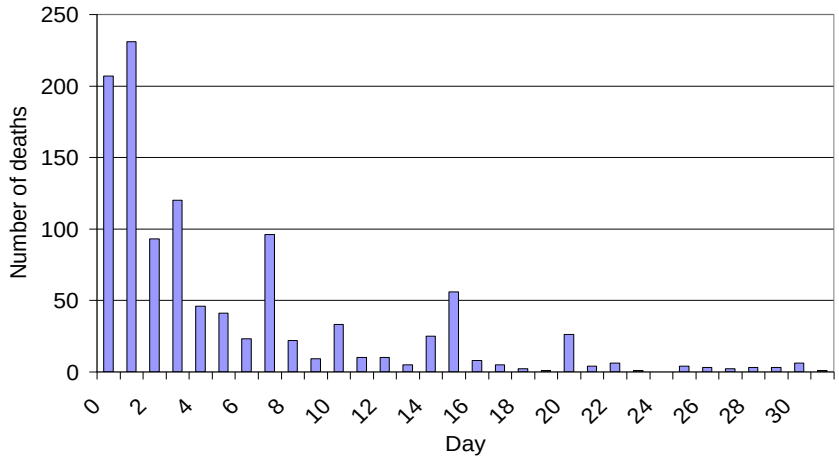


Figure d: Latin America and the Caribbean (data from 9 surveys)

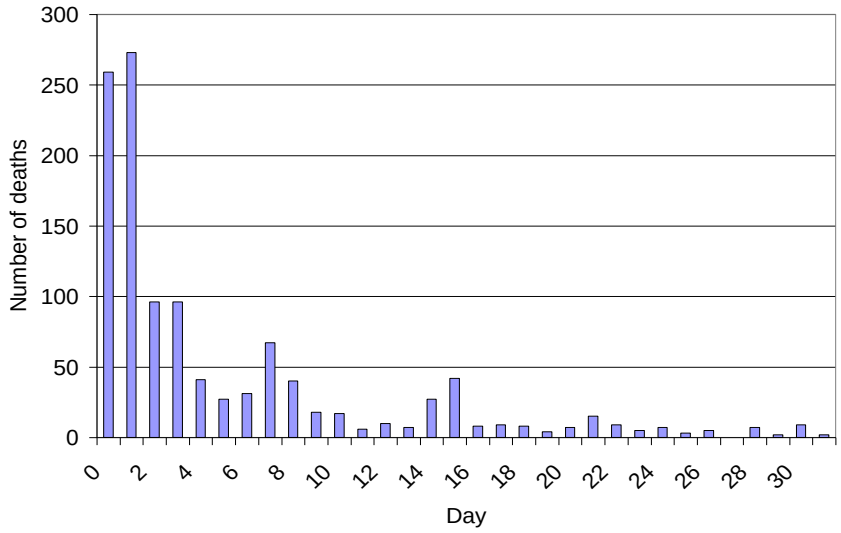
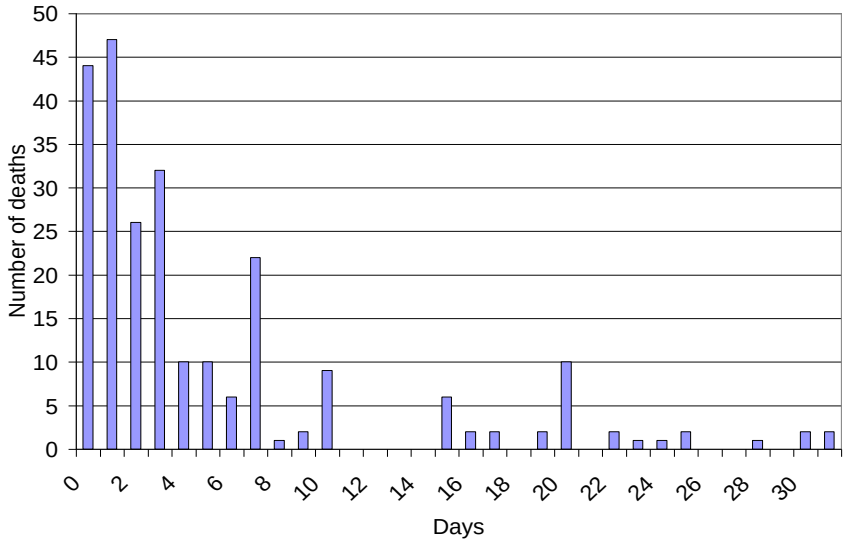


Figure e: Central Asia (data from 4 surveys)



Appendix 2: Bar graphs showing the distribution of infant mortality by month of reported death

Figure 2 (a-e) Distribution of infant mortality by month of reported death

Figure a: Sub-Saharan Africa (data from 30 surveys)

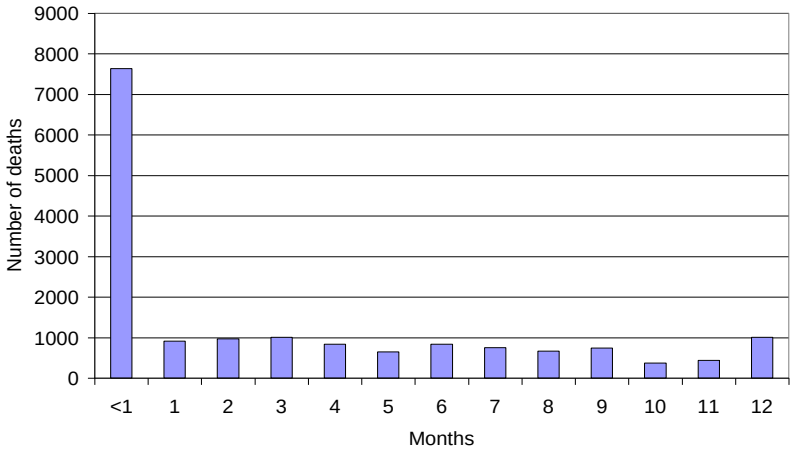


Figure b: South and South East Asia (data from 8 surveys)

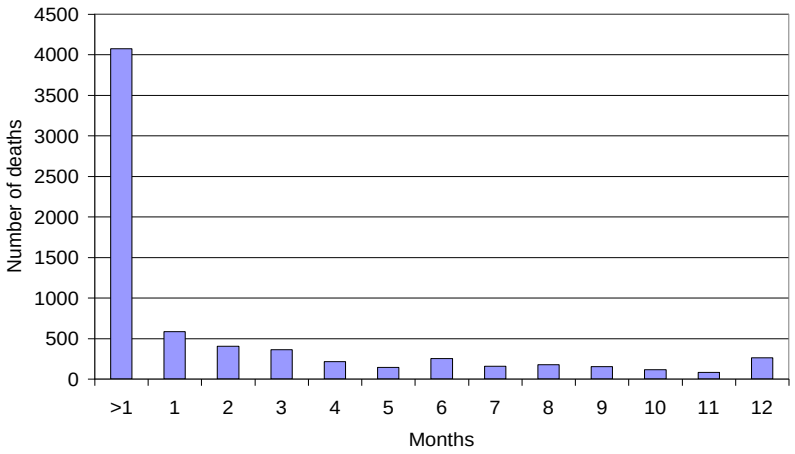


Figure c: North Africa and Western Asia (data from 6 surveys)

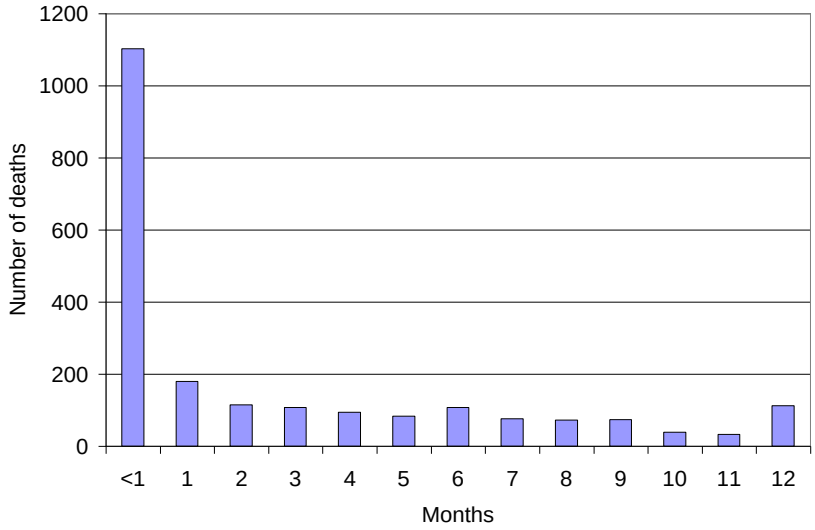


Figure d: Latin America and the Caribbean (data from 9 surveys)

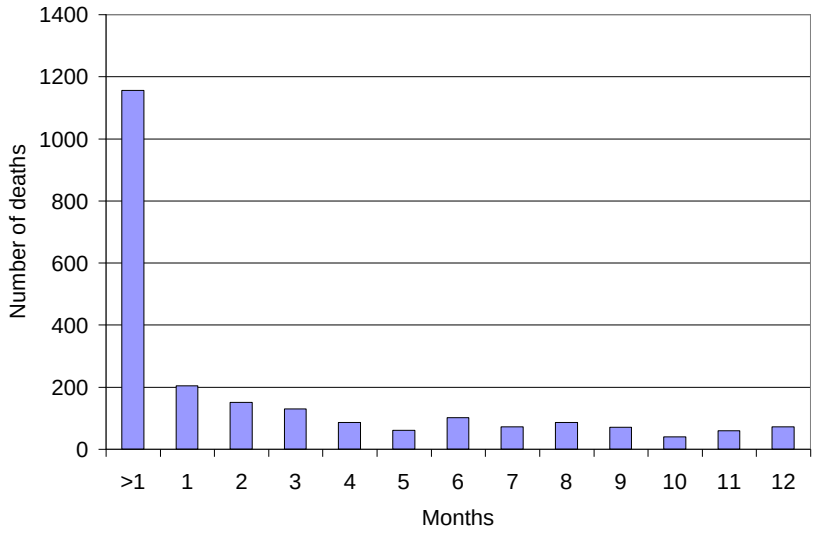
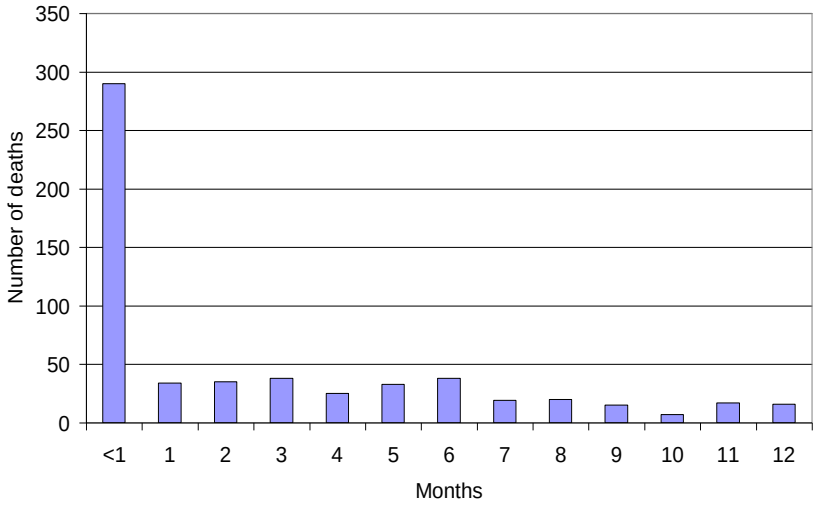


Figure e: Central Asia (data from 4 surveys)



Appendix 3: Standard errors for neonatal mortality estimates from DHS II surveys (5 year rates)

Country	NMR	Standard Error	Relative Standard error (S/E as proportion of NMR)	Date of later survey with available SEs (if any)	Relative Standard error of later survey
Burkina Faso	43.2	3.49	0.081		
Cameroon	33.1	4.20	0.127		0.097
Madagascar	38.9	3.27	0.084		
Malawi	41.2	3.56	0.087	2000	0.059
Namibia	31.5	3.16	0.100		
Niger	40.7	3.32	0.081		
Nigeria	42.2	2.90	0.069	1999	0.081
Rwanda	38.6	3.07	0.079		
Senegal	34.9	2.77	0.080		
Tanzania	37.9	3.65	0.096	1999	0.116
Zambia	43.5	2.91	0.068	2000	0.075
Egypt	32.8	2.46	0.075		
Indonesia	31.7	2.42	0.076		
Jordan	21.4	1.88	0.088		
Morocco	31.4	2.96	0.094		
Pakistan	48.9	4.19	0.086		
Yemen	40.9	3.00	0.073		
N E Brazil	26.1	3.76	0.144		
Columbia	10.8	1.66	0.153		
Dominican Republic	23.7	3.74	0.158		
Paraguay	19.4	2.48	0.128		
Peru	25.3	1.75	0.069	2000	0.081

Source: Curtis 1995, p.19
Note: DHS II surveys were carried out between 1990 and 1993.

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