The extent of underestimation of maternal mortality in developing countries from Demographic and Health Surveys (DHS) data

Saifuddin Ahmed[1], Qingfeng Li[1], Carolyn Scrafford[1] and Tom Pullum[2]
[1]Johns Hopkins university, Baltimore, MD, USA
[2]DHS Program, ICF International, Rockville, MD, USA

Correspondence:
Saifuddin Ahmed, MBBS, PhD
Associate Professor
Department of Population, Family and Reproductive Health
Bloomberg School of Public Health
Johns Hopkins University
615 North Wolfe Street #E4642
Baltimore, MD 21205
Tel:(410) 614-4952
e-mail: sahmed@jhu.edu

Abstract

Background: The Demographic Health Surveys (DHS) remain as the main source of empirical data on maternal mortality in developing countries. Using direct sisterhood method, DHS estimates maternal mortality ratio (MMR) from the respondents' sibling history. This method relies on the reporting of the timing of a sister's death in relationship to pregnancy, delivery and postpartum period for classifying female deaths in to maternal deaths. The objective of this paper is to show the problems of underestimation of MMR from DHS data due to high missing or non-response rate of the timing of female deaths.

Method: We used data from 111 Demographic and Health Surveys with siblings history in 46 countries of Sub-Saharan Africa, North Africa, Asia, and Latin America. First, we examine the extent of the missing response on the timing of female deaths and the problems of ascertaining maternal deaths in each survey. Then, we examine the influence of the missing response on MMR estimate by four statistical methods of handling missing data: complete case analysis, weighting for non-response rate, hotdeck imputation and multiple imputations.

Results: Many countries had very high non-response rate on the timing of female deaths (median 10%; mean 11.9%). The MMR estimates of the standard DHS method and complete case analysis (cases with non-response on maternal death classification questions removed) were almost similar (country average MMR: 526 deaths per 100,000 live births) and likely to be biased in the presence of high non-response on timing of deaths. In contrast, all other methods (weighting, hotdeck and multiple imputations) show considerably higher underestimation bias in MMR estimates (country average MMR 590, 599 and 603, respectively).

Conclusion: The current reporting of DHS significantly underestimates maternal mortality in several developing countries. Appropriate correction for non-response rate on the timing of female deaths may reduce underestimation bias of maternal mortality estimates.

Extended Abstract

Introduction

The evaluation of safe motherhood programs and monitoring the progress in achieving the Millennium Development Goal-5 (MDG-5) of reducing maternal mortality ratio by three-quarters between 1990 and 2015 remains a major challenge because of the difficulties in measuring maternal mortality in the context of weak information systems. The accurate estimation of maternal mortality is notoriously difficult in developing countries primarily because of the lack of a complete vital registration system. Globally, only 13% of births are covered by vital registration systems. Even where a good vital registration system is available, such as in most developed countries, misclassification and underestimation of maternal mortality is not uncommon. For example, in the US 39%, in the UK 56% and in France 50% maternal deaths are misclassified in vital records.

In the absence of complete vital registration with good attribution of causes of deaths, the most commonly employed methods for maternal mortality estimates are household surveys with direct death inquiry, indirect and direct sisterhood methods, and reproductive age mortality surveys (RAMOS). For the countries where no data are available on maternal mortality, regression based methods are used to estimate maternal mortality.

The Demographic Health Surveys (DHS) have long been the primary source of data and information to monitor and track key indicators of a country's health status among its population, including maternal mortality. With the launch of the Safe Motherhood Initiative in 1987 and the subsequent increased interest in maternal health and mortality, the DHS responded one year later and introduced the maternal mortality module to the DHS questionnaire in 1988. Since 1988, the maternal module has been implemented in 60 countries representing all regions of the DHS including 39 countries in sub-

Saharan Africa, 15 countries in North Africa/West Asia/Europe, and 6 countries in Latin America and the Caribbean. Further, the majority of these countries have collected data on maternal health and mortality in more than one survey period allowing governments and donor agencies to track and measure a country's progress towards achieving MDG 5. The DHS employs sisterhood method for maternal mortality estimation.

Graham et al. proposed the indirect sisterhood method in late 1980s, primarily to overcome the needs of large sample size in household surveys, and several developing countries adopted the method. In this method, the female respondents are asked about the survival status of their siblings, and in case of a sister's death, the timing of death in relationship to pregnancy status of the index sister. By piggybacking on existing surveys, the cost of maternal mortality estimation is generally low. No specific causes of deaths are inquired in this method, and as a result, the accidental or incidental causes of maternal deaths could not the ascertained. Rutenberg and Sullivan proposed a direct sisterhood method which has overcome some limitations of the indirect method. The direct sisterhood method also estimates pregnancy related deaths like indirect method, rather than maternal deaths, but the estimates reflect the deaths over a shorter period (approximately last 7 years).

The direct estimation of maternal mortality is the method currently used in the DHS maternal mortality module and in the datasets included in this analysis. This method is based on the same principles as the indirect method but collects additional data to allow for the calculation of person years of exposure times necessary for the calculation of age-specific mortality rates. Maternal mortality is still defined based on the timing of the sister's death with relation to pregnancy but includes deaths up through 2 months as opposed to 6 weeks. This revision was made to ease reporting and recall burden on the respondent of 6 weeks vs 2 months with little impact on the accuracy of the indicators. The DHS maternal mortality module questionnaire starts out by asking questions about both brothers and sisters of the respondent that were born to the natural mother in the following order:

1.) How many children did your mother give birth to including you?
2.) If more than one birth (the respondent), how many birth occurred before the respondent was born?

Then for each sibling reported in #2 above, the following questions were asked of the respondent:

3.) What was the name of your oldest brother or sister?
4.) Is that sibling male or female?
5.) Is that sibling still alive?
6.) How old is that sibling?
7.) How many years ago did the sibling die (if applicable)?
8.) How old was the sibling when they died?

If the sibling was female and dead the following questions are asked:

9.) Was the sibling pregnant?
10.) Did she die during childbirth?
11.) Did she die within two months after the end of a pregnancy or childbirth?
12.) How many live born children did she give birth to during her lifetime?

An earlier study by Stanton, Abderrhim , and Hill, based on 14 DHS surveys, suggests high non-response rate on reporting of the timing of female deaths (question #9,10, and 11 above). The major purpose of the current study is to examine the extent of missingness on the timing of female deaths and its impact on the ascertainment of maternal mortality in DHS data.

Data and Method:

The study uses data from 111 Demographic and Health Surveys (DHS), which are nationally representative surveys that use standardized questionnaires to collect extensive information from women of reproductive age (15 to 49 years). All surveys carried out in the period covering 1988 to 2012 having sibling history module for adult mortality estimation were included in the analysis. Data from four countries were restricted and were excluded from the analysis. Demographic and Health Surveys are usually carried out at four-year intervals and several countries have data from multiple rounds, which also provided an opportunity to examine the changes in quality of data over time.

First, we examine the extent of the missingness/non-response rate on the timing of female deaths, which is used to classify deaths in to maternal deaths in all the available surveys. Second, we estimate MMR employing the method used by DHS. Third, we employ four statistical methods for addressing missing response to examine the effect of non-response rate on underestimation bias in MMR estimates. We use (a) complete case analysis (missing cases dropped from analysis), (b) weighting for non-response (inversely weighted by the response rate which inflated the maternal death proportions by the extent of missingness), (c) hotdeck imputation and (d) multiple imputation methods.

Results

Table 1 shows maternal mortality rate (maternal deaths per 1,000 woman-years of exposure) and maternal mortality ratio (deaths per 100,000 live births) with 95% confidence intervals. The confidence intervals were estimated with jackknife method.

Table 1: Maternal mortality rate and ratio estimates with 95% confidence internals from 106 Demographic and Health Surveys: 1988-2012

Country	DHS Round	Year of survey	GFR	MMRate	MMR	95% CI	
						LL	UL
Sub-Saharan Africa							
Benin	DHS-III	1996	205	1.020	498	375	621
Benin	DHS-V	2006	193	0.773	400	328	472
Burkina Faso	DHS-III	1998-99	219	0.962	440	305	575
Burkina Faso	DHS-VI	2010	200	0.682	341	276	405
Burundi	DHS-VI	2010-11	194	0.972	500	379	621
CAR	DHS-III	1994-95	185	2.553	1380	1141	1620
Cameroon	DHS-III	1998	178	0.909	511	375	647
Cameroon	DHS-IV	2004	174	1.198	689	568	810
Cameroon	DHS-VI	2011	170	1.330	782	649	914
Chad	DHS-III	1996-97	223	1.863	836	665	1007
Chad	DHS-IV	2004	225	2.472	1098	685	1512
Congo (Brazzaville)	DHS-V	2005	154	1.204	781	495	1068
Congo (Brazzaville)	DHS-VI	2011-12	161	0.687	426	277	575
Congo Democratic Republic	DHS-V	2007	201	1.087	542	409	674
Cote d'Ivoire	DHS-III	1994	197	1.179	597	418	777
Cote d'Ivoire	DHS-V	2005	163	0.880	539	325	754
Cote d'Ivoire	DHS-VI	2011-12	164	1.004	614	448	780
Ethiopia	DHS-IV	2000	181	1.577	872	707	1036
Ethiopia	DHS-IV	2005	185	1.240	671	549	793
Ethiopia	DHS-VI	2011	169	1.140	675	543	808
Gabon	DHS-III	2000-01	149	0.771	519	331	707
Gabon	DHS-VI	2012	131	0.412	316	180	451
Guinea	DHS-III	1999	196	1.033	528	380	676
Guinea	DHS-IV	2005	181	2.030	1119	912	1327
Guinea	DHS-VI	2012	173	1.250	724	536	911
Kenya	DHS-III	1998	160	1.191	743	594	892
Kenya	DHS-IV	2003	165	0.834	506	400	612
Kenya	DHS-V	2008-09	157	0.818	520	348	691
Lesotho	DHS-IV	2004-05	114	1.066	936	684	1187
Liberia	DHS-V	2006-07	172	1.698	990	683	1297
Madagascar	DHS-III	1997	202	0.990	490	367	614
Madagascar	DHS-IV	2003-04	172	0.887	517	348	686
Madagascar	DHS-V	2008-09	163	0.812	498	404	593
Malawi	DHS-II	1992	212	1.302	615	406	824
Malawi	DHS-IV	2000	210	2.357	1123	959	1288
Malawi	DHS-IV	2004-05	204	1.997	981	823	1138
Malawi	DHS-V	2010	197	1.331	675	571	778
Mali	DHS-III	1995-96	234	1.265	541	437	645
Mali	DHS-IV	2001	231	1.340	581	453	710
Mali	DHS-V	2006	224	1.036	462	377	548
Mozambique	DHS-III	1997	186	0.538	289	123	455
Mozambique	DHS-IV	2003-04	188	0.877	466	366	566
Mozambique	DHS-VI	2011	187	0.763	408	305	511
Namibia	DHS-II	1992	161	0.473	294	194	394
Namibia	DHS-IV	2000	134	0.442	330	203	458
Namibia	DHS-V	2006-07	114	0.580	509	360	658

Country	DHS Round	Year of survey	GFR	MMRate	MMR	95% CI LL	95% CI UL
Niger	DHS-II	1992	250	1.535	614	475	753
Niger	DHS-V	2006	242	1.716	708	578	838
Niger	DHS-VI	2012	264	1.411	535	427	643
Nigeria	DHS-III	1999	173	0.497	287	189	384
Nigeria	DHS-V	2008	186	1.014	545	477	614
Rwanda	DHS-IV	2000	179	2.789	1559	1324	1795
Rwanda	DHS-IV	2005	176	1.330	757	623	891
Rwanda	DHS-VI	2010-11	154	0.751	487	395	579
Sao Tome and Principe	DHS-V	2008-09	152	0.177	116	27	205
Senegal	DHS-II	1992-93	200	0.998	498	367	629
Senegal	DHS-IV	2005	166	0.666	401	314	487
Senegal	DHS-VI	2010-11	163	0.790	484	340	628
Sierra Leone	DHS-V	2008	175	1.487	849	615	1082
South Africa	DHS-III	1998	97	0.146	150	79	222
Swaziland	DHS-V	2006-07	131	0.774	589	394	783
Tanzania	DHS-III	1996	193	1.179	612	461	764
Tanzania	DHS-IV	2004-05	185	1.119	605	476	735
Tanzania	DHS-V	2009-10	178	0.880	494	376	611
Togo	DHS-III	1998	175	0.732	417	302	532
Uganda	DHS-III	1995	235	1.245	529	401	657
Uganda	DHS-IV	2000-01	236	1.248	529	420	638
Uganda	DHS-V	2006	225	0.939	418	317	519
Uganda	DHS-VI	2011	211	0.912	433	318	548
Zambia	DHS-III	1996-97	206	1.337	649	522	777
Zambia	DHS-IV	2001-02	198	1.443	729	589	869
Zambia	DHS-V	2007	198	1.170	591	453	730
Zimbabwe	DHS-III	1994	152	0.556	365	253	477
Zimbabwe	DHS-IV	1999	140	0.904	647	476	819
Zimbabwe	DHS-V	2005-06	135	0.829	613	461	764
Zimbabwe	DHS-VI	2010-11	132	1.262	960	781	1139
North Africa							
Jordan	DHS-III	1997	145	0.051	35	8	62
Morocco	DHS-II	1992	130	0.493	378	255	501
Morocco	DHS-IV	2003-04	81	0.221	272	186	359
Asia							
Cambodia	DHS-IV	2000	127	0.554	437	328	547
Cambodia	DHS-V	2005-06	106	0.499	472	341	603
Cambodia	DHS-V	2010-11	95	0.197	206	125	287
Indonesia	DHS-III	1994	96	0.396	411	284	537
Indonesia	DHS-III	1997	91	0.262	288	137	438
Indonesia	DHS-IV	2002-03	82	0.271	331	222	440
Indonesia	DHS-V	2007	80	0.166	209	137	281
Indonesia	DHS-VI	2012	75	0.235	313	222	404
Nepal	DHS-III	1996	162	0.875	539	395	683

Country	DHS Round	Year of survey	GFR	MMRate	MMR	95% CI LL	95% CI UL
Nepal	DHS-V	2006	252	0.334	133	84	181
Philippines	DHS-II	1993	131	0.229	175	120	230
Philippines	DHS-III	1998	119	0.206	172	123	222
Timor-Leste	DHS-VI	2009-10	172	0.959	557	411	703
Latin America							
Bolivia	DHS-III	1993-94	160	0.577	360	218	503
Bolivia	DHS-IV	2003-04	134	0.281	210	146	274
Bolivia	DHS-V	2008	115	0.309	268	183	353
Brazil	DHS-III	1996	83	0.153	184	104	263
Dominican Republic	DHS-IV	2002	99	0.163	165	75	254
Dominican Republic	DHS-V	2007	88	0.152	173	104	242
Guatemala	DHS-III	1995	166	0.257	155	96	214
Haiti	DHS-IV	2000	148	0.773	523	364	682
Haiti	DHS-V	2005-06	124	0.777	628	481	776
Peru	DHS-II	1991-92	121	0.205	169	113	224
Peru	DHS-III	1996	119	0.316	265	208	322
Peru	DHS-IV	2000	99	0.183	185	130	241
Peru	DHS-V	2003-08	81	0.163	203	150	256
Peru	DHS-VI	2011	80	0.126	157	96	219

Table 2 shows the missingness in the timing of female deaths, which ranges from negligible 0% to very high of 42%. Almost half of the countries have more than 10% non-response rate on the timing of female deaths.

The Demographic and Health Surveys estimate maternal mortality rate by:

$$\frac{number\ of\ maternal\ deaths}{number\ of\ woman-years\ (aged\ 15-49\ years)}\ x\ 1000 = MMRate$$

The MMRate and MMRatio can be calculated from each other by applying the general fertility rate (GFR) in the country of interest using the following formula:

$$\frac{MMRate}{GFR} = MMRatio$$

The GFR is the ratio of live births to women aged 15-49 years.

In calculating MMRate, DHS includes only confirmed maternal deaths in the numerator. If the extent of maternal deaths is considered to be similar in the missing cases, the number of maternal deaths are liklely to be increased by the inverse probability of response rate, i.e., 1/(1-response rate) factor. We show the impact of this weighted estimate of MMR in the last column of Table 2.

Table 2: Extent of missing response on the timing of death for the ascertainment of maternal mortality in 105 Demographic and Health Surveys: 1988-2012

Rank in underestimation	Region	Country	DHS round	Year of Survey	Missing % on timing of deaths (maternal or non-maternal)	MMR	MMR Corrected for missing response
1	Latin America & Caribbean	Peru	DHS-VI	2011	0.1	157	158
2	Asia	Timor-Leste	DHS-VI	2009-10	0.5	557	560
3	Asia	Nepal	DHS-III	1996	1.0	539	544
4	Asia	Cambodia	DHS-V	2010-11	1.8	206	210
5	Sub-Saharan Africa	Uganda	DHS-VI	2011	1.9	433	441
6	Asia	Nepal	DHS-V	2006	2.7	133	136
7	Sub-Saharan Africa	Ethiopia	DHS-IV	2000	2.7	872	896
8	Sub-Saharan Africa	Burundi	DHS-VI	2010-11	3.1	500	516
9	Sub-Saharan Africa	Rwanda	DHS-VI	2010-11	3.3	487	504
10	Sub-Saharan Africa	Chad	DHS-III	1996-97	3.6	836	867
11	Latin America & Caribbean	Peru	DHS-V	2003-08	3.7	203	211
12	Sub-Saharan Africa	Burkina Faso	DHS-VI	2010	3.8	341	354
13	Sub-Saharan Africa	Kenya	DHS-III	1998	3.9	743	773
14	Asia	Cambodia	DHS-V	2005-06	4.0	472	492
15	Sub-Saharan Africa	Kenya	DHS-IV	2003	4.5	506	529
16	Sub-Saharan Africa	Ethiopia	DHS-VI	2011	4.7	675	709
17	Sub-Saharan Africa	Tanzania	DHS-V	2009-10	4.8	494	518
18	Sub-Saharan Africa	CAR	DHS-III	1994-95	4.8	1,380	1,451
19	Sub-Saharan Africa	Cameroon	DHS-VI	2011	4.9	782	822
20	Sub-Saharan Africa	Tanzania	DHS-IV	2004-05	5.0	605	637
21	Sub-Saharan Africa	Rwanda	DHS-IV	2000	5.0	1,559	1,642
22	Sub-Saharan Africa	Chad	DHS-IV	2004	5.1	1,098	1,157
23	Asia	Indonesia	DHS-III	1997	5.1	288	303
24	Asia	Cambodia	DHS-IV	2000	5.5	437	463
25	Latin America & Caribbean	Bolivia	DHS-V	2008	5.6	268	284
26	Sub-Saharan Africa	Benin	DHS-III	1996	5.7	498	528
27	Sub-Saharan Africa	Zimbabwe	DHS-VI	2010-11	5.9	960	1,020
28	Latin America & Caribbean	Haiti	DHS-V	2005-06	6.0	628	668

Rank in underestimation	Region	Country	DHS round	Year of Survey	Missing % on timing of deaths (maternal or non-maternal)	MMR	MMR Corrected for missing response
29	Sub-Saharan Africa	Mali	DHS-III	1995-96	6.4	541	578
30	Sub-Saharan Africa	Mozambique	DHS-IV	2003-04	6.5	466	499
31	Sub-Saharan Africa	Niger	DHS-VI	2012	6.6	535	573
32	Sub-Saharan Africa	Malawi	DHS-IV	2004-05	6.9	981	1,054
33	Sub-Saharan Africa	Zambia	DHS-IV	2001-02	6.9	729	784
34	Sub-Saharan Africa	Cote d'Ivoire	DHS-III	1994	7.0	597	642
35	Sub-Saharan Africa	Zambia	DHS-V	2007	7.1	591	636
36	Sub-Saharan Africa	Guinea	DHS-VI	2012	7.2	724	780
37	Sub-Saharan Africa	Congo Democratic Republic	DHS-V	2007	7.2	542	584
38	Sub-Saharan Africa	Congo (Brazzaville)	DHS-VI	2011-12	7.2	426	460
39	Sub-Saharan Africa	Malawi	DHS-IV	2000	7.3	1,123	1,212
40	Sub-Saharan Africa	Uganda	DHS-V	2006	7.3	418	451
41	Sub-Saharan Africa	Tanzania	DHS-III	1996	7.4	612	661
42	Sub-Saharan Africa	Zambia	DHS-III	1996-97	7.6	649	703
43	Latin America & Caribbean	Haiti	DHS-IV	2000	7.8	523	567
44	Sub-Saharan Africa	Guinea	DHS-IV	2005	8.0	1,119	1,216
45	Sub-Saharan Africa	Malawi	DHS-V	2010	8.0	675	733
46	Sub-Saharan Africa	Ethiopia	DHS-IV	2005	8.3	671	732
47	Sub-Saharan Africa	Zimbabwe	DHS-III	1994	8.7	365	400
48	Sub-Saharan Africa	Cote d'Ivoire	DHS-V	2005	8.9	539	592
49	Sub-Saharan Africa	Kenya	DHS-V	2008-09	9.2	520	572
50	Sub-Saharan Africa	Rwanda	DHS-IV	2005	9.4	757	835
51	Asia	Indonesia	DHS-III	1994	9.6	411	455
52	Sub-Saharan Africa	Lesotho	DHS-IV	2004-05	9.7	936	1,036
53	Sub-Saharan Africa	Zimbabwe	DHS-V	2005-06	10.0	613	681
54	North Africa	Morocco	DHS-IV	2003-04	10.0	272	303
55	Sub-Saharan Africa	Madagascar	DHS-III	1997	10.2	490	546
56	Sub-Saharan Africa	Swaziland	DHS-V	2006-07	10.3	589	656
57	Sub-Saharan Africa	Congo (Brazzaville)	DHS-V	2005	10.4	781	872
58	Asia	Indonesia	DHS-IV	2002-03	10.6	331	370
59	Latin America & Caribbean	Dominican Republic	DHS-V	2007	10.6	173	193
60	Sub-Saharan Africa	Mozambique	DHS-VI	2011	10.8	408	457
61	Latin America & Caribbean	Bolivia	DHS-III	1993-94	10.8	360	404
62	Latin America & Caribbean	Bolivia	DHS-IV	2003-04	10.9	210	236
63	Sub-Saharan Africa	Senegal	DHS-II	1992-93	11.1	498	560
64	Sub-Saharan Africa	Benin	DHS-V	2006	11.1	400	450
65	Sub-Saharan Africa	Cameroon	DHS-IV	2004	11.5	689	779
66	Sub-Saharan Africa	Uganda	DHS-IV	2000-01	11.7	529	599
67	Sub-Saharan Africa	Burkina Faso	DHS-III	1998-99	11.8	440	499

Rank in underesti mation	Region	Country	DHS round	Year of Survey	Missing % on timing of deaths (maternal or non-maternal)	MMR	MMR Corrected for missing response
68	Sub-Saharan Africa	Niger	DHS-V	2006	12.4	708	808
69	Sub-Saharan Africa	Namibia	DHS-V	2006-07	12.5	509	582
70	Sub-Saharan Africa	Cameroon	DHS-III	1998	12.6	511	584
71	Asia	Indonesia	DHS-VI	2012	12.9	313	359
72	Sub-Saharan Africa	Niger	DHS-II	1992	13.2	614	707
73	Sub-Saharan Africa	Zimbabwe	DHS-IV	1999	13.4	647	747
74	Latin America & Caribbean	Peru	DHS-III	1996	13.9	265	307
75	Sub-Saharan Africa	Mali	DHS-IV	2001	14.1	581	677
76	Asia	Indonesia	DHS-V	2007	14.9	209	245
77	Sub-Saharan Africa	Uganda	DHS-III	1995	14.9	529	622
78	Sub-Saharan Africa	Madagascar	DHS-V	2008-09	15.0	498	586
79	Sub-Saharan Africa	Gabon	DHS-VI	2012	15.3	316	373
80	Sub-Saharan Africa	Togo	DHS-III	1998	15.9	417	496
81	Sub-Saharan Africa	Gabon	DHS-III	2000-01	16.8	519	623
82	Sub-Saharan Africa	Cote d'Ivoire	DHS-VI	2011-12	17.1	614	740
83	Latin America & Caribbean	Peru	DHS-II	1991-92	17.1	169	204
84	Sub-Saharan Africa	Malawi	DHS-II	1992	17.4	615	744
85	Sub-Saharan Africa	Senegal	DHS-IV	2005	18.1	401	489
86	Sub-Saharan Africa	Madagascar	DHS-IV	2003-04	18.6	517	635
87	Latin America & Caribbean	Peru	DHS-IV	2000	19.1	185	229
88	Sub-Saharan Africa	Nigeria	DHS-V	2008	19.2	545	674
89	Asia	Philippines	DHS-III	1998	19.9	172	215
90	Latin America & Caribbean	Brazil	DHS-III	1996	20.5	184	231
91	Sub-Saharan Africa	Guinea	DHS-III	1999	21.9	528	676
92	Sub-Saharan Africa	South Africa	DHS-III	1998	22.5	150	194
93	Latin America & Caribbean	Dominican Republic	DHS-IV	2002	22.6	165	213
94	Sub-Saharan Africa	Mali	DHS-V	2006	22.7	462	598
95	Sub-Saharan Africa	Liberia	DHS-V	2006-07	22.7	990	1,280
96	Sub-Saharan Africa	Mozambique	DHS-III	1997	24.4	289	382
97	North Africa	Morocco	DHS-II	1992	25.0	378	504
98	Latin America & Caribbean	Guatemala	DHS-III	1995	25.5	155	209
99	Sub-Saharan Africa	Sierra Leone	DHS-V	2008	25.8	849	1,143
100	Asia	Philippines	DHS-II	1993	29.1	175	247
101	North Africa	Jordan	DHS-III	1997	31.3	35	51
102	Sub-Saharan Africa	Namibia	DHS-IV	2000	31.3	330	481
103	Sub-Saharan Africa	Namibia	DHS-II	1992	35.5	294	456
104	Sub-Saharan Africa	Nigeria	DHS-III	1999	35.5	287	445
105	Sub-Saharan Africa	Sao Tome and Principe	DHS-V	2008-09	41.6	116	199

We also employed three other statistical methods for addressing missing response: complete case analysis (woman person-years for missing cases excluded from the denominator of MMRate calculation), hotdeck imputation (single imputation) and Rubin's multiple imputation method (10 imputations used). The results are shown in Table 3. Side by side comparisons of all five methods are shown graphically in Figure 1 and 2 for Sub-Saharan and Other countries, respectively.

Complete case results are almost similar to the standard DHS estimate of MMR. Maternal deaths are rare events and the exclusions of person-years of sisters with missing response from denominators has negligible effects on the MMRate and thus on MMR estimates. Imputation methods, however, increased MMR estimates substantially.

Table 3: Comparison of MMR estimates from imputation and complete case analyses with DHS data

		Hotdeck imputation			Multiple imputation			Complete case analysis		
Country	Year	MMR	LL	UL	MMR	LL	UL	MMR	LL	UL
Sub-Saharan Africa										
Benin	1996	561	424	699	541	410	674	505	381	630
Benin	2006	474	397	552	458	382	534	403	331	476
Burkina Faso	1998-99	518	374	663	493	352	635	442	307	578
Burkina Faso	2010	369	302	437	359	293	425	343	279	408
Burundi	2010	515	394	637	521	399	645	500	380	621
CAR	1994-95	1481	1236	1727	1454	1211	1697	1397	1157	1638
Cameroon	1998	630	475	786	632	472	793	524	380	669
Cameroon	2004	829	699	960	803	668	939	699	578	821
Cameroon	2011	826	692	961	820	686	955	782	650	915
Chad	1996-97	853	678	1029	875	697	1055	845	670	1021
Chad	2004	1220	753	1688	1227	760	1694	1174	709	1640
Congo (Brazzaville)	2005	887	590	1185	912	598	1228	824	524	1125
Congo (Brazzaville)	2011-12	476	322	631	476	320	633	432	283	582
Congo Democratic Republic	2007	615	476	755	633	483	784	548	414	683
Cote d'Ivoire	1994	659	476	843	637	456	820	606	427	786
Cote d'Ivoire	2005	610	387	834	605	383	828	558	341	776
Cote d'Ivoire	2011-12	770	587	954	754	572	937	615	450	781
Ethiopia	2000	907	740	1075	918	748	1089	883	718	1049
Ethiopia	2005	796	661	932	743	614	873	681	558	805
Ethiopia	2011	708	574	843	713	578	850	676	544	809
Gabon	2000	672	474	871	676	469	884	526	338	715
Gabon	2012	465	298	633	425	263	587	319	184	455
Guinea	1999	720	551	890	703	533	875	539	389	690
Guinea	2005	1257	1033	1482	1246	1025	1469	1161	947	1376

		Hotdeck imputation			Multiple imputation			Complete case analysis		
Country	Year	MMR	LL	UL	MMR	LL	UL	MMR	LL	UL
Guinea	2012	803	609	998	806	610	1002	743	554	933
Kenya	1998	786	634	939	785	632	938	744	596	893
Kenya	2003	550	435	666	560	446	675	514	406	623
Kenya	2008-09	604	427	782	595	419	773	522	351	694
Lesotho	2004	1125	842	1409	1045	782	1308	945	692	1199
Lesotho	2009	1550	1203	1898	1579	1222	1936	1256	939	1574
Liberia	2007	1265	941	1590	1277	951	1603	1002	693	1312
Madagascar	1997	560	431	690	565	436	696	492	369	616
Madagascar	2003-04	609	435	784	635	444	828	520	351	690
Madagascar	2008-09	618	509	728	604	499	710	503	409	598
Malawi	1992	679	466	893	742	522	963	618	409	828
Malawi	2000	1243	1066	1421	1216	1047	1387	1131	966	1297
Malawi	2004	1106	942	1271	1082	916	1249	987	829	1146
Malawi	2010	740	634	847	733	626	842	675	572	779
Mali	1995-96	575	466	685	591	484	700	546	442	651
Mali	2001	685	545	826	681	544	819	583	455	712
Mali	2006	631	525	738	616	512	720	474	387	562
Mozambique	1997	360	185	536	423	220	628	290	123	458
Mozambique	2003	533	424	643	525	417	635	487	382	593
Mozambique	2011	468	360	577	462	355	570	412	309	516
Namibia	1992	505	366	645	438	312	564	295	195	396
Namibia	2000	490	325	656	536	369	705	333	205	462
Namibia	2006-07	573	418	729	591	434	749	510	362	659
Niger	1992	766	593	940	809	636	982	616	477	756
Niger	2006	834	691	978	812	674	950	723	593	854
Nigeria	1999	447	325	570	464	338	590	294	196	393
Nigeria	2008	712	634	791	705	626	785	552	483	622
Rwanda	2000	1647	1406	1889	1726	1477	1977	1588	1349	1828
Rwanda	2005	847	709	986	835	695	975	760	626	895
Rwanda	2010	512	420	605	511	418	604	492	401	584
Sao Tome and Principe	2008-09	165	65	266	290	127	453	117	29	206
Senegal	1992-93	611	468	755	625	478	773	499	368	631
Senegal	2005	560	456	665	517	417	618	417	328	507
Senegal	2010-11	486	343	630	488	344	632	485	342	629
Sierra Leone	2008	1173	909	1438	1242	966	1518	903	667	1140
South Africa	1998	179	103	256	201	116	287	151	80	223
Swaziland	2006-07	686	477	896	680	469	892	593	398	789
Tanzania	1996	682	525	840	674	516	833	616	465	768
Tanzania	2004-05	629	497	762	657	522	793	613	484	743
Tanzania	2010	563	438	689	545	423	668	507	389	626
Togo	1998	498	377	620	485	361	610	419	304	535

		Hotdeck imputation			Multiple imputation			Complete case analysis		
Country	Year	MMR	LL	UL	MMR	LL	UL	MMR	LL	UL
Uganda	1995-96	626	489	764	643	499	788	539	410	669
Uganda	2000-01	625	504	747	636	517	757	541	432	651
Uganda	2006	442	339	546	463	357	571	424	321	528
Uganda	2011	446	330	563	447	331	564	433	318	549
Zambia	1996	695	564	827	714	581	847	652	524	781
Zambia	2001-02	807	658	957	796	649	945	733	593	874
Zambia	2007	633	492	775	643	500	787	592	454	731
Zimbabwe	1994	377	263	492	405	285	526	366	254	479
Zimbabwe	1999	766	587	946	784	596	972	649	478	821
Zimbabwe	2005-06	680	525	836	693	537	849	613	462	765
Zimbabwe	2010	995	813	1178	1007	825	1191	963	784	1143
North Africa										
Jordan	1997	56	20	93	82	20	145	35	9	62
Morocco	1992	513	362	665	544	400	689	379	257	502
Morocco	2003-04	321	230	413	321	229	414	273	187	360
Asia										
Cambodia	2000	481	366	597	473	360	588	438	329	548
Cambodia	2005	488	357	620	494	362	627	472	342	603
Cambodia	2010	207	127	288	211	130	293	207	127	288
Indonesia	1994	471	340	603	470	334	607	413	287	540
Indonesia	1997	345	184	507	334	175	494	315	158	473
Indonesia	2002-03	378	262	495	378	261	496	334	224	445
Indonesia	2007	258	181	336	277	197	358	209	138	281
Indonesia	2012	345	252	439	358	262	455	313	222	405
Nepal	1996	546	401	692	550	405	696	539	395	684
Nepal	2006	136	88	185	139	88	190	133	85	182
Niger	2012	575	466	685	573	462	686	540	433	648
Philippines	1993	274	208	341	264	198	331	176	121	232
Philippines	1998	227	170	285	250	188	313	173	124	223
Timor-Leste	2009-10	562	416	709	561	415	708	558	412	705
Latin America and Caribbean										
Bolivia	1994	411	265	558	416	267	566	361	219	504
Bolivia	2003	248	179	318	248	178	318	211	148	275
Bolivia	2008	296	205	388	290	202	379	271	187	356
Brazil	1996	259	159	360	262	163	362	184	105	264
Dominican Republic	2002	228	130	327	244	146	343	168	79	258
Dominican Republic	2007	201	124	279	202	128	276	174	106	243
Guatemala	1995	252	167	338	238	158	319	156	97	216
Haiti	2000	531	371	692	568	389	747	524	365	684
Haiti	2005-06	649	501	798	671	518	826	630	483	778

		Hotdeck imputation			Multiple imputation			Complete case analysis		
Country	Year	MMR	LL	UL	MMR	LL	UL	MMR	LL	UL
Peru	1991-92	299	224	375	304	226	383	176	119	234
Peru	1996	329	264	395	325	261	389	269	212	327
Peru	2000	234	170	299	254	186	323	188	133	244
Peru	2004-06	221	166	277	220	165	276	207	154	261
Peru	2007-08	221	166	277	220	165	276	207	154	261
Peru	2011	159	98	221	171	102	242	158	97	220

Figure 1: Comparison of MMR estimates by five methods with Demographic and Health Surveys (DHS) in Sub-Saharan Africa

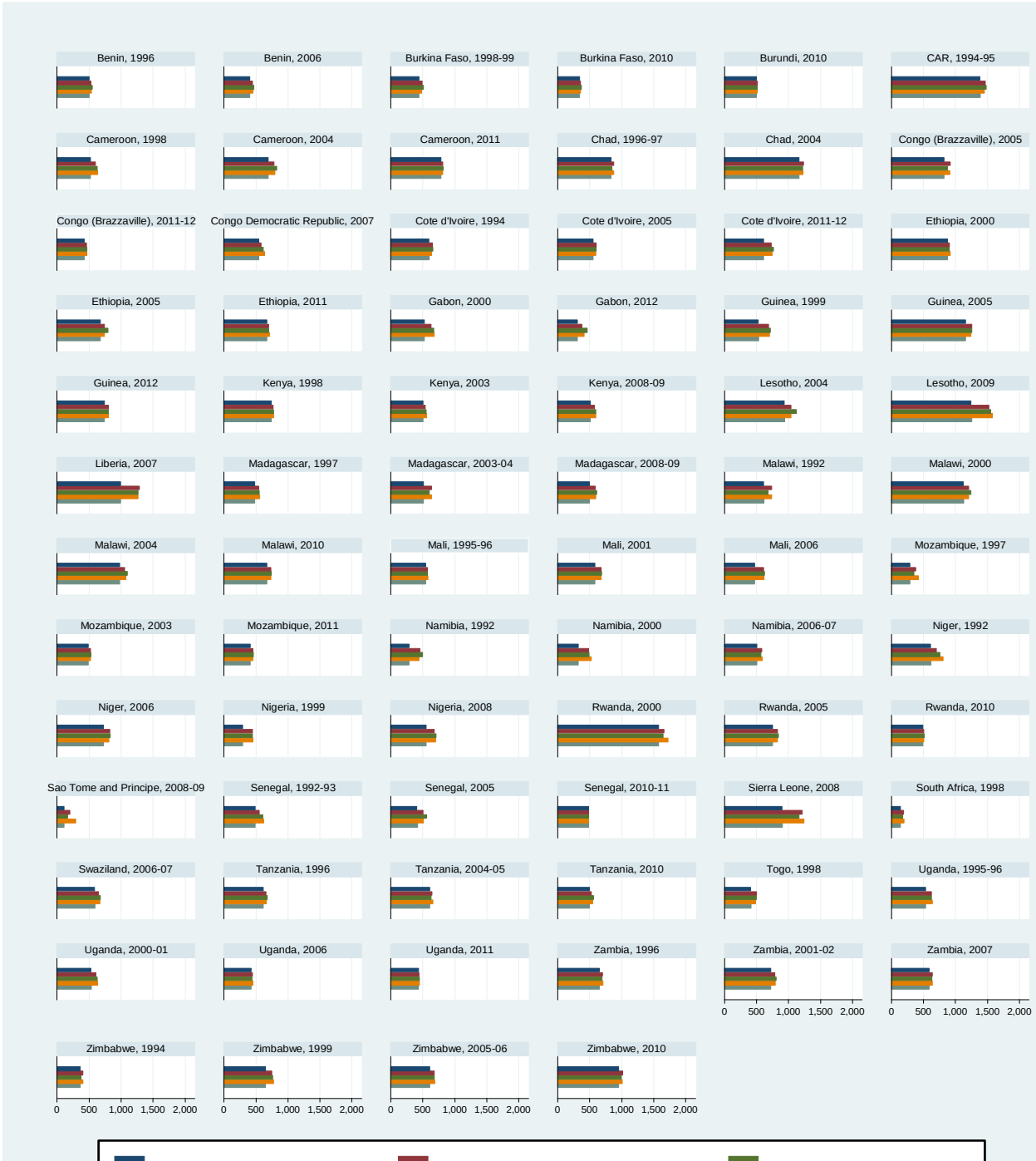
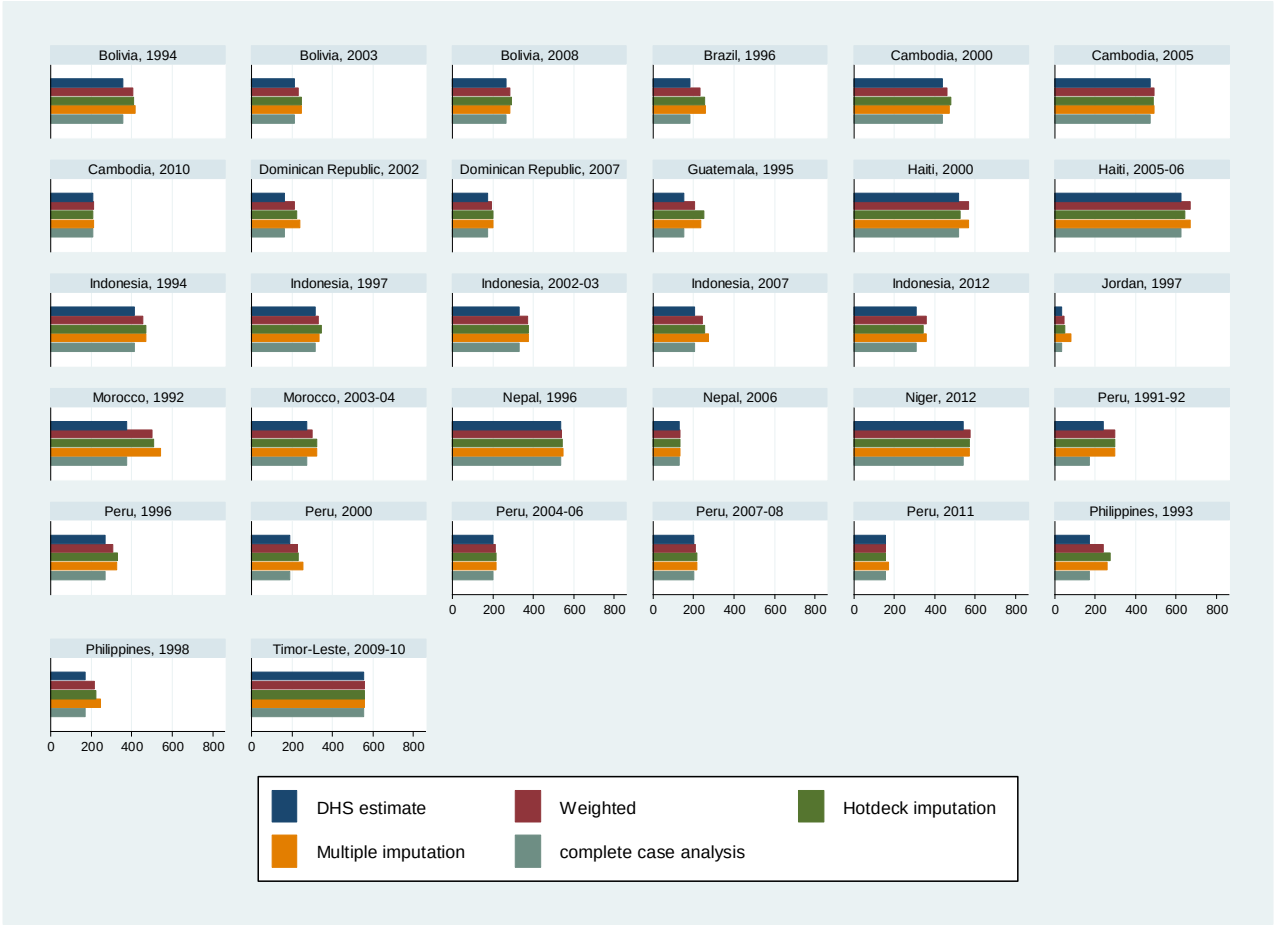

Benin, 1996
Benin, 2006
Burkina Faso, 1998-99
Burkina Faso, 2010
Burundi, 2010
CAR, 1994-95
Cameroon, 1998
Cameroon, 2004
Cameroon, 2011
Chad, 1996-97
Chad, 2004
Congo (Brazzaville), 2005
Congo (Brazzaville), 2011-12
Congo Democratic Republic, 2007
Cote d'Ivoire, 1994
Cote d'Ivoire, 2005
Cote d'Ivoire, 2011-12
Ethiopia, 2000
Ethiopia, 2005
Ethiopia, 2011
Gabon, 2000
Gabon, 2012
Guinea, 1999
Guinea, 2005
Guinea, 2012
Kenya, 1998
Kenya, 2003
Kenya, 2008-09
Lesotho, 2004
Lesotho, 2009
Liberia, 2007
Madagascar, 1997
Madagascar, 2003-04
Madagascar, 2008-09
Malawi, 1992
Malawi, 2000
Malawi, 2004
Malawi, 2010
Mali, 1995-96
Mali, 2001
Mali, 2006
Mozambique, 1997
Mozambique, 2003
Mozambique, 2011
Namibia, 1992
Namibia, 2000
Namibia, 2006-07
Niger, 1992
Niger, 2006
Nigeria, 1999
Nigeria, 2008
Rwanda, 2000
Rwanda, 2005
Rwanda, 2010
Sao Tome and Principe, 2008-09
Senegal, 1992-93
Senegal, 2005
Senegal, 2010-11
Sierra Leone, 2008
South Africa, 1998
Swaziland, 2006-07
Tanzania, 1996
Tanzania, 2004-05
Tanzania, 2010
Togo, 1998
Uganda, 1995-96
Uganda, 2000-01
Uganda, 2006
Uganda, 2011
Zambia, 1996
Zambia, 2001-02
Zambia, 2007
Zimbabwe, 1994
Zimbabwe, 1999
Zimbabwe, 2005-06
Zimbabwe, 2010
0 500 1,000 1,500 2,000
DHS estimate
Weighted
Hotdeck imputation
Multiple imputation
complete case analysis

Figure 2: Comparison of MMR estimates by five methods with Demographic and Health Surveys (DHS) in Asia, North Africa and Latin America



Conclusion

More than 50% of the Demographic and Health Surveys have 10% or more missing response on the timing of female deaths, which is used maternal mortality classification. The standard maternal mortality estimates in DHS ignores missing response on the classification of maternal deaths and thus substantially underestimates MMR for a large number of developing countries. Appropriate imputation method, preferably multiple imputation method, which probabilistically takes in to account uncertainly in imputation values, may be considered for minimizing underestimation bias in MMR.