Sample Selection Bias in Adult Mortality Estimates from Mobile Phone Surveys. Evidence From 25 Low- And Middle-Income Countries

Abstract

BACKGROUND

Mobile phone surveys are gaining traction in low- and middle-income countries (LMICs), but mobile phone ownership (MPO) is not universal, potentially introducing sample selection bias in ensuing estimates.

OBJECTIVE

To evaluate MPO-associated sample selection bias in adult mortality estimates from sibling survival histories.

METHODS

Using data from 25 Demographic and Health Surveys, we (i) used logistic regression to assess the association of MPO and socio-demographic background characteristics; (ii) used sibling survival histories (SSH) to estimate the probability of dying in adulthood ($_{45}q_{15}$) in a general population sample of women of reproductive age and a subsample of women who own a mobile phone, (iii) and we used post-stratification weighting to correct bias in adult mortality estimates from the subsample of Mobile Phone Owners (MPOs).

RESULTS

MPO correlated with socio-demographic characteristics in a predictable fashion. Summary indices of adult mortality ($_{45}q_{15}$) using reports on siblings of MPOs aligned with the general population estimate in 20 out of 25 countries. Significant bias in excess of 10% was identified in Papua New Guinea, Burundi, Rwanda, Haiti and Zimbabwe, with the estimate being mostly lower when based on reports of MPOs. Post-stratification weighting alleviated this bias to levels that were no longer statistically significant. Bias was typically most pronounced at both ends of the age spectrum.

CONCLUSIONS

MPO associated selection bias in adult mortality estimates from SSH is generally modest. Post-stratification weighting on respondents' attributes can partially alleviate this bias where it exists.

CONTRIBUTION

This study supports efforts for the use of mobile phone surveys for demographic data collection.

Introduction

Civil Registration and Vital Statistics (CRVS) systems are the gold standard for tracking mortality and causes of death. However, the availability and functionality of such systems varies and is often defective in high mortality settings – where they are most needed. The World Bank estimated that over 110 low- and middle-income countries (LMICs) have deficient CRVS systems (World Bank Group, 2018), leading to a striking 60% of deaths left unregistered (Mikkelsen et al., 2015).

In the absence of comprehensive death registration, other data sources – including censuses and household surveys – are used as alternatives. These are often costly, and time-consuming, and are impractical in cases of conflicts, disasters or health crises. For example, COVID-19 resulted in the suspension and/or delay of many face-to-face data collection activities (UNICEF, 2020; USAID, 2022), precisely when timely data were needed to formulate a policy response. The WHO reports that only 16 out of the 106 Member States in African, Eastern Mediterranean, South-East Asian, and Western Pacific regions had empirical data enabling the calculation of excess COVID-19 deaths (WHO, 2020).

Mobile Phone Surveys (MPS) are an attractive alternative for demographic data collection in LMICs, due to their cost-effectiveness and convenience. They require little or no interviewer travel and can be implemented when restrictions on mobility exist, including in conflicts, natural disasters or disease outbreaks (L'Engle et al., 2018). However, there is a legitimate concern that this modality might introduce or exacerbate biases in demographic estimates. The evidence suggests that mobile phone owners (MPOs) in LMICs are more often male, wealthier, higher educated, and are more likely to reside in urban areas. These attributes are potentially correlated with demographic indices, and that could introduce selection bias in the ensuing estimates (Blumenstock & Eagle, 2012; Wesolowski et al., 2012). A prior study revealed potential biases in fertility and under-five mortality rates when estimates relied solely on data from women who own or have access to mobile phones (Sánchez-Páez et al., 2023). Although poststratification using basic information could mitigate bias in mortality estimates for young children, it appears ineffective in correcting biases in fertility estimates. The question of whether adult mortality estimates face similar biases remains uncertain, given the distinct correlates of child and adult mortality (Menashe-Oren & Masquelier, 2022) The Demographic and Health Surveys (DHS) are often the main source of data on adult mortality in LMICs. DHS use the Sibling Survival Histories (SSH) to obtain adult mortality estimates inquire about the survival status of maternal siblings of the respondent and are most typically administered to women of reproductive age.

Recent DHS also ask about mobile phone ownership (MPO) among respondents, and this allows us to investigate sample selection bias in SSH from a mobile phone survey.

In this study, we use DHS, first to investigate the association between MPO and sociodemographic background characteristics of the respondents. Second, we compare adult mortality estimates from a subsample of MPOs with those from the total sample. Third, we evaluate whether post-stratification weights can be used to correct sample selection bias in adult mortality estimates if the SSH were only administered among MPOs. With post-stratification, the distribution of survey respondents is adjusted to match the overall population characteristics, improving the representativeness and accuracy of the results (Smith, 1991).

Materials and Methods

We utilized data from available DHS surveys containing information on MPO and adult mortality (Table 1). None of the DHS surveys collected both MPO data and SSH from male interviews, restricting our analysis to female respondents.

Out of the 25 identified surveys, 20 were conducted in sub-Saharan Africa, and two in Eastern and South-eastern Asia. These surveys covered 25 low-and-middle-income countries and were conducted between 2015 and 2021.

Initially, we examined the prevalence of MPO in each survey. Subsequently, we employed logistic regression to evaluate the relationship between MPO and socio-demographic characteristics of female respondents, including age, educational level (none, primary, secondary or higher), wealth, marital status (married or cohabiting, not married nor cohabiting), area of residence (urban or rural), region of residence, and household size (below 5, 5 to 9, or more than 9 residents). The wealth index was constructed using Principal Component Analysis (PCA) on household amenities (electricity, roofing quality, and water source) and dichotomized based on the median value.

Subsequently, we calculated age-specific mortality rates for 5-year age groups (nMx), and we obtained the probability of dying between ages 15 and 60 (45q15) by linking age-specific probabilities of dying. The mortality estimates referred to the period 0-6 completed years before the survey.

We computed these metrics for (i) the entire sample of female respondents, (ii) the sample of MPOs, and (iii) the sample of MPOs after applying post-stratification weights to mimic the effect of post-stratification of a mobile phone survey sample on mortality estimates. Post-stratification weights were computed using iterative proportional fitting (raking) to match the weighted MPOs sample with the distribution of the entire female respondent sample in terms of age, education, wealth, type and region of residence and household size.

We also calculated the ratio of age-specific mortality rates (nMx) and the summary index 45q15 for MPOs versus the entire sample, both before and after applying post-stratification weights, to identify any potential sample selection bias associated with MPO.

Confidence intervals (CI) were generated from 2500 samples using resampling with replacement while considering the DHS sample design. We used the 2.5th and 97.5th percentiles to construct 95% CI for each parameter. Our analyses were conducted using Stata 16 and Matlab (StataCorp, 2023; The MathWorks Inc., 2023).

Results

Mobile phone ownership (MPO) prevalence

MPO varied substantially between countries and was typically lower in low-income countries and among women (Table 1). In four surveys (Burundi, Malawi, Ethiopia, and Papa New Guinea), less than 40% of women of reproductive age owned a mobile phone. In contrast, five countries (Cambodia, Mauritania, South Africa, the Gambia, and Zimbabwe) had a female MPO above 70%. In Malawi, where the absolute gender difference in MPO was the largest, 87% of men owned a mobile phone, but only 32% of women did (Table 1).

Table 1: Mobile Ownership by Survey, and World Bank Income Level and sex (sorted from lowest to highest ownership among women)

Survey	World bank income level	Sample size	Ownership, % (95%-CI)	
			Male	Female
Burundi 2016	Low	17269	45.8 (43.5, 48)	23.6 {21.6, 25.5}
Ethiopia 2016	Low	15683	53.7 (50.7, 56.6)	27.3 {24.2, 30.4}
Malawi 2015	Low	24562	52.1 (49.9, 54.2)	32.8 {30.7, 35}
Papua N. Guinea 2017	Low-middle	15198	50.4 (47.3, 53.4)	34.3 {31.3, 37.3}
Sierra Leone 2019	Low	15574	64.2 (62, 66.5)	42.6 {40.1, 45.1}
Uganda 2016	Low	18506	65.8 (63.8, 67.9)	45.5 {43.2, 47.8}
Liberia 2019	Low	8065	61.1 (57.4, 64.8)	46.7 {42.3, 51.2}
Rwanda 2019	Low	14634	61.1 (59.2, 63.1)	47.9 {45.9, 50}
Benin 2017	Low-middle	15928	79.6 (78.2, 80.9)	51.1 {49, 53.2}

Angola 2015	Low	14379	70.2 (67.3, 73.1)	51.2 {48, 54.5}
Tanzania 2015	Low-middle	13266	68.8 (66.7, 71)	52.2 {49.6, 54.8}
Zambia 2018	Low	13683	66 (63.9, 68.1)	53 {50, 56}
Nigeria 2018	Low-middle	41821	81.2 (80, 82.4)	55.3 {53.4, 57.2}
Haiti 2016	Low-middle	15513	67.3 (65.2, 69.4)	55.5 {53.2, 57.8}
Mali 2018	Low	10519	87.5 (86, 89)	58.3 {55.4, 61.3}
Cameroon 2018	Low-middle	14677	76.9 (74.6, 79.1)	63.1 {59.9, 66.3}
Timor-Leste 2016	Low-middle	12607	76.2 (73.9, 78.5)	65.6 {63.7, 67.5}
Senegal 2017	Low-middle	16787	84.2 (82.9, 85.6)	68 {65.6, 70.3}
Zimbabwe 2015	Low-middle	9955	73.8 (71.9, 75.6)	69.5 {67.3, 71.6}
Nepal 2016	Low-middle	12862	89.3 (88.1, 90.6)	72.6 {70.6, 74.7}
Gambia 2019	Low	11865	86.5 (84.8, 88.2)	76.4 {74.8, 78}
Mauritania 2020	Low-middle	15714	85.7 (84.1, 87.2)	76.7 {74.7, 78.8}
Cambodia 2021	Low-middle	19496	91.3 (90.3, 92.3)	84.8 {83.6, 86.1}
Gabon 2019	Upp-middle	11043	89.8 (88.5, 91.1)	88.9 {87.8, 89.9}
South Africa 2016	Upp-middle	8514	88.5 (86.8, 90.1)	91.2 {90.2, 92.2}

Female MPO correlated in a predictable manner with sociodemographic background characteristics (Table 2). It was often concentrated in mid-adulthood (25-45), and was always least likely in the 15-19 age group. Compared to women with no education, primary educated women were more likely to own a mobile phone in all surveys; the highest odds ratio (OR) observed in Burundi (OR 3.03; 95%CI 2.67-3.44) and Ethiopia (OR 3.59, 95%CI 2.79-4.62), where female MPO was the lowest. The OR was not significant in Gabon and South Africa, where female MPO was highest.

Higher scores on the household amenity index were positively correlated with MPO in nearly all surveys (not significant in Cambodia).

Married or cohabiting women typically had lower odds of owning a phone than women who were not married or living together, most notably in Rwanda (0.46, 95%CI 0.42-0.52). Senegal, Nepal, Gambia, and Mauritania are the only surveys where the OR was above 1, suggesting a positive association. The association of MPO with marital status was insignificant in Timor-Leste, Zimbabwe, Gabon and South Africa after controlling for other covariates.

Residence in rural areas was negatively associated with MPO in most surveys, most notably in Ethiopia (OR = 0.25; 95% CI: 0.18 – 0.35) and Burundi (OR = 0.25; 95% CI: 0.22 – 0.72), the two countries with the lowest ownership prevalence among women. The association was not significant in South Africa. A bigger household size was almost always negatively correlated with mobile phone ownership.

Table 2: Factors associated with mobile phone ownership among female respondents in 25 DHS surveys (Odds Ratios).

	Effect of age groups compared to the 15-19 age group						Education (compared to no education)		Wealth	Marital status	Are of residence	Household size	
Survey	20-24	25-29	30-34	35-39	40-44	45-49	Primary	Secondary or higher	Above the median compared to below	Married or cohabiting compared to not married nor cohabiting	Rural residence compared to urban residence	*5 to 9*	*>9*
Burundi 2016	4.20	7.16	8.04	6.99	7.14	6.67	3.03	11.87	1.46	0.94	0.27	0.97	1.04
Ethiopia 2016	1.75	2.41	2.43	1.49	1.51	1.59	3.59	19.36	1.87	0.70	0.28	0.72	0.66
Malawi 2015	2.93	4.44	5.18	5.98	5.39	5.62	2.18	8.10	2.22	0.91	0.41	0.81	0.75
Papua N Guinea 2017	2.06	2.03	1.99	2.35	2.60	2.52	2.72	11.17	2.13	0.74	0.43	0.84	0.85
Sierra Leone 2019	4.11	6.48	8.41	10.01	8.77	8.10	1.73	4.91	1.46	0.75	0.28	0.85	0.89
Uganda 2016	5.16	8.71	10.57	12.50	12.50	12.81	2.29	7.97	1.86	0.69	0.50	0.70	0.61
Liberia 2019	2.73	4.65	6.61	6.25	5.95	7.02	1.47	4.83	1.34	0.67	0.27	0.77	0.86
Rwanda 2019	6.18	7.45	8.71	11.08	10.51	9.37	1.07	1.13	2.17	0.47	0.47	1.07	1.13
Benin 2017	5.20	7.65	8.86	11.17	11.19	10.65	2.20	4.54	1.83	0.86	0.61	0.86	0.72
Angola 2015	2.45	3.85	5.05	5.91	4.35	5.52	2.30	10.07	1.71	0.65	0.36	0.84	0.91
Tanzania 2015	4.54	6.58	7.81	8.78	8.76	7.24	2.62	6.16	1.85	0.79	0.44	0.85	0.74
Zambia 2018	3.75	5.81	8.67	9.96	9.81	8.69	2.10	8.80	2.042	0.65	0.45	0.95	0.92
Nigeria 2018	3.54	4.96	5.10	5.91	5.74	5.75	2.26	6.05	2.07	0.83	0.52	0.69	0.59
Haiti 2016	4.24	7.11	7.69	8.38	9.11	6.52	2.49	10.23	1.50	0.68	0.66	0.73	0.75
Mali 2018	2.02	2.27	2.43	2.03	2.13	2.12	1.51	2.89	1.86	0.81	0.46	0.68	0.58
Cameroon 2018	4.36	6.18	6.91	8.34	7.09	8.08	2.55	6.59	2.15	0.81	0.41	0.75	0.61
Timor-Leste 2016	3.37	3.41	3.49	2.64	1.90	1.37	1.59	4.19	1.32	0.95	0.65	0.75	0.57
Senegal 2017	4.28	4.39	4.97	4.72	5.01	4.50	1.80	3.50	1.66	1.29	0.63	0.72	0.63
Zimbabwe 2015	3.16	5.25	6.85	7.57	7.02	8.99	2.15	5.24	1.72	0.85	0.46	0.77	0.80
Nepal	3.78	4.12	4.52	2.54	1.80	1.32	2.03	5.23	1.17	1.96	0.81	0.49	0.38
Gambia 2019	4.32	5.56	5.84	5.33	6.87	5.98	1.55	2.88	1.44	1.28	0.63	0.88	0.82
Mauritania 2020	3.03	3.32	3.41	3.86	3.55	3.33	1.96	3.16	1.59	1.72	0.63	0.69	0.53
Cambodia 2021	1.99	1.90	1.56	1.33	0.87	0.63	2.11	7.15	1.09	0.78	0.56	0.82	0.64
Gabon 2019	5.81	7.31	10.56	11.12	10.88	12.91	1.39	4.63	1.49	0.94	0.44	0.61	0.46
South Africa 2016	3.63	7.58	6.69	6.00	5.11	9.75	1.65	7.04	1.37	0.92	0.86	0.57	0.51

Odds ratios for the association of socio-demographic characteristics with mobile phone ownership among female respondents in the 25 surveys analyzed. The odds ratios are from a logistic regression that adjusts for age group, highest education level attempted, region of residence, area of residence (rural/urban), a binary dummy variable for marital/cohabitation status, and household size (five to nine, nine or more). The results for the region of residence are not presented for space limitations and are available on request from the authors.

Table 2 colour coding

OR above 1 and significant
OR below 1 and significant
OR not statistically different from 1

MPO among women tended to be significantly more likely in the region of the country where the capital is located. In Rwanda and Senegal, all regions had significantly lower odds of MPO, compared to Kigali and Dakar, and in 18 surveys, none of the regions had higher OR of MPO compared to the capital region (table available on request).

Adult mortality among siblings of MPOs versus total sample

Age-specific mortality rates from the entire sample and those derived from the subsample of mobile phone owners are shown in Figure 1. As one would expect, adult mortality rapidly increases with age of the sibling.

Figure 1: Age-specific mortality rates from SSH: all women of reproductive age versus mobile phone owners, by country (25 DHS)

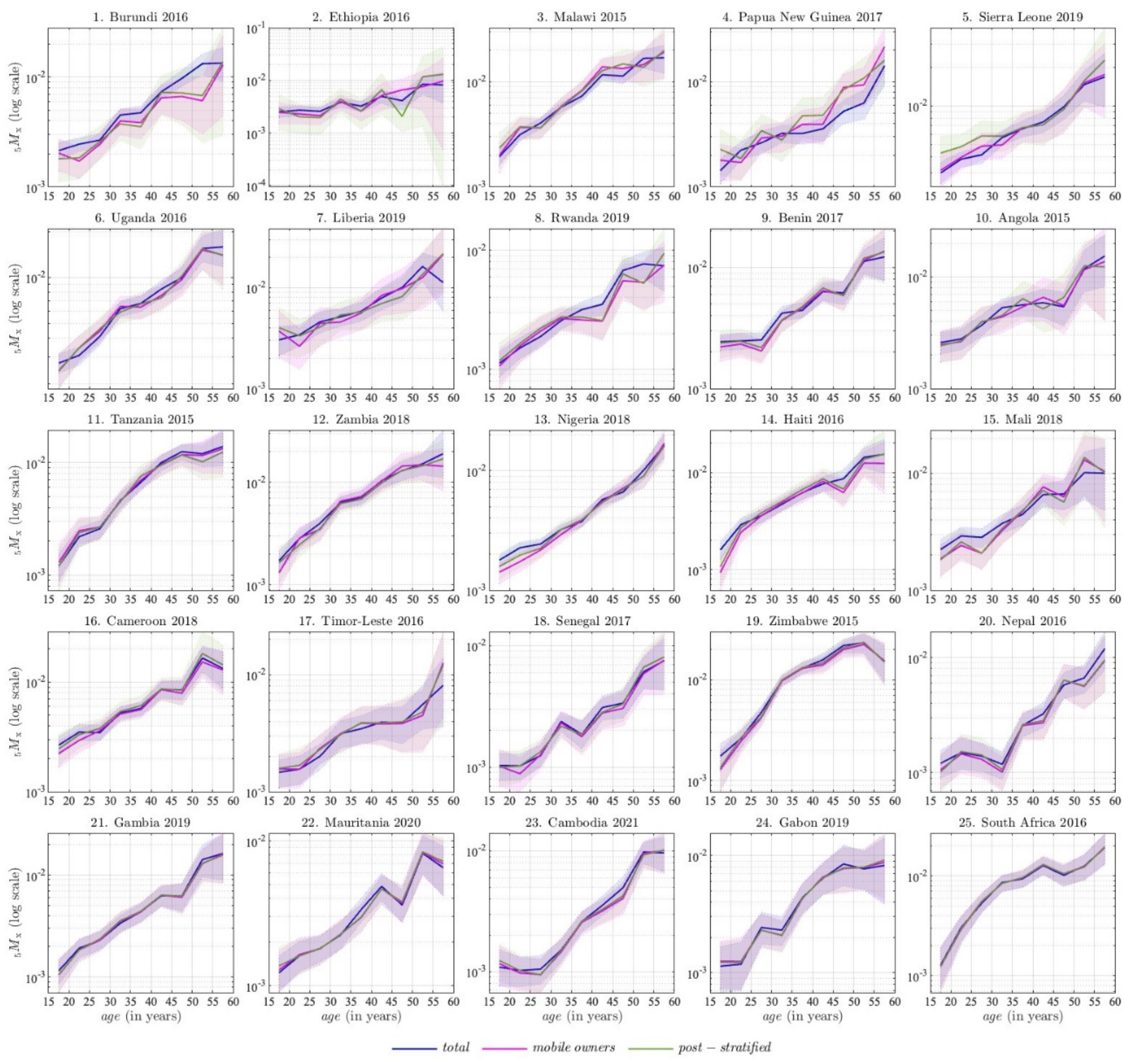


Figure 1: This figure illustrates the age specific mortality rates across 25 surveys, with the 95% confidence intervals. It presents two distinct estimates: in blue, the age specific mortality rates obtained from the total sample of female respondents; in pink, the age specific mortality rates obtained from reports of mobile phone owners only with no adjustment and in green the age specific mortality rates obtained from reports of mobile phone owners adjusted using post-stratification weights. The post-stratification weights have been calculated based on the total sample distribution of age, type and region of residence, education level, wealth above or below the mean, and household size.

Figure 1 also shows that differences in the estimates derived from the entire sample and the subsample of MPOs are relatively small. This is even clearer in Figure 2, which shows the bootstrap distribution of the ratio of the probability ${}_{45}q_{15}$ computed from MPOs relative to the entire population. A ratio of one means there is no difference between the two estimates and that sample selection bias is absent.

Figure 2: Ratio of 45q15 derived from reports of mobile phone owners relative to the total sample: before and after post-stratification weighting, by country (25 DHS surveys).

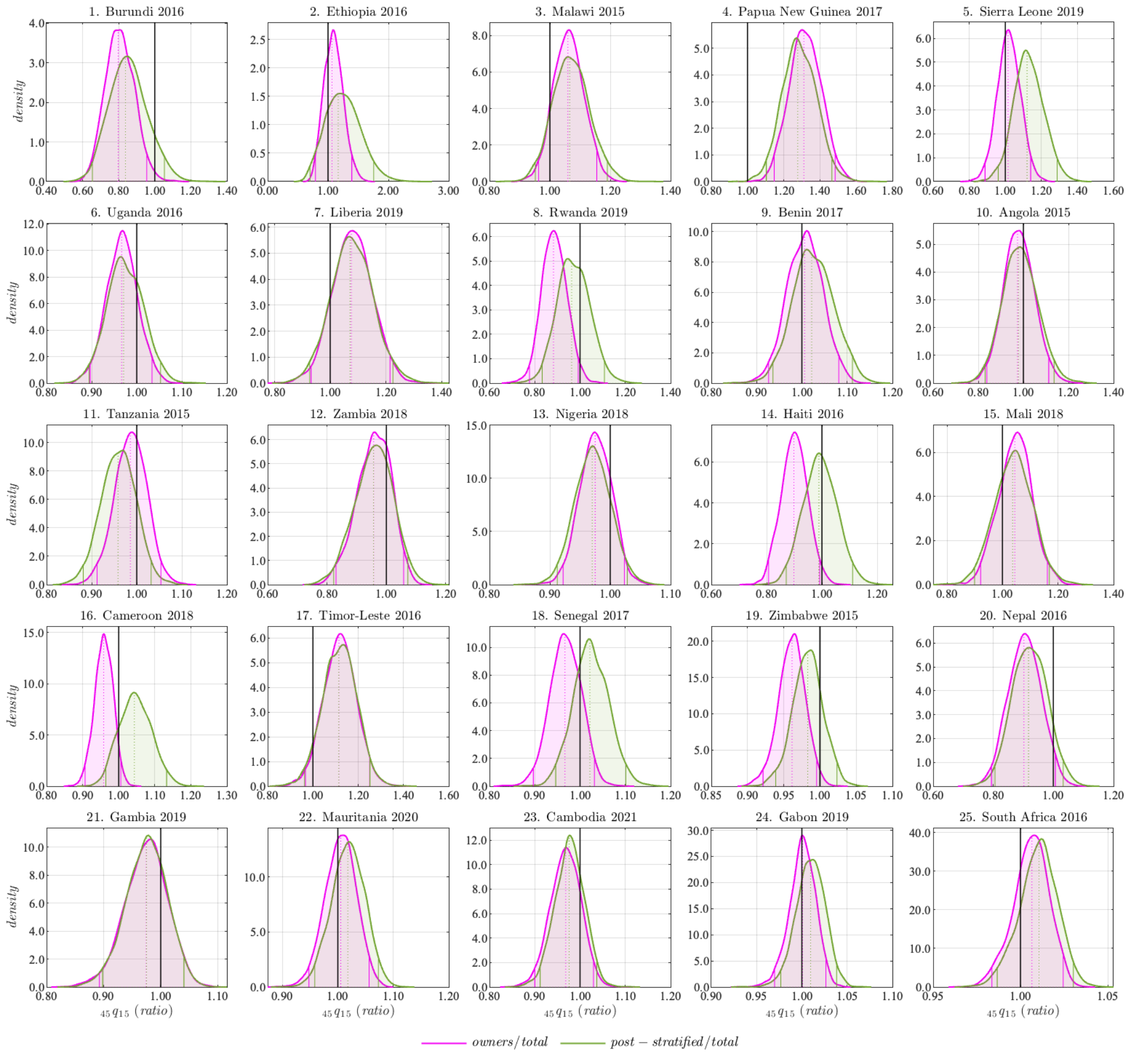


Figure 2 This figure illustrates the ratio of 45q15 derived from reports of mobile phone owners relative to the total sample, from 2500 bootstrapped samples across 25 surveys, with the 95% confidence intervals around the ratio. It presents two distinct estimates: in pink, the ratio of mobile phone owners estimate weighted according to Demographic and Health Surveys (DHS), relative to the total sample, and in green, the ratio of the mobile phone owners estimate adjusted by post-stratification weights. The post-stratification weights have been calculated based on the total sample distribution of age, type and region of residence, education level, wealth above or below the mean, and household size.

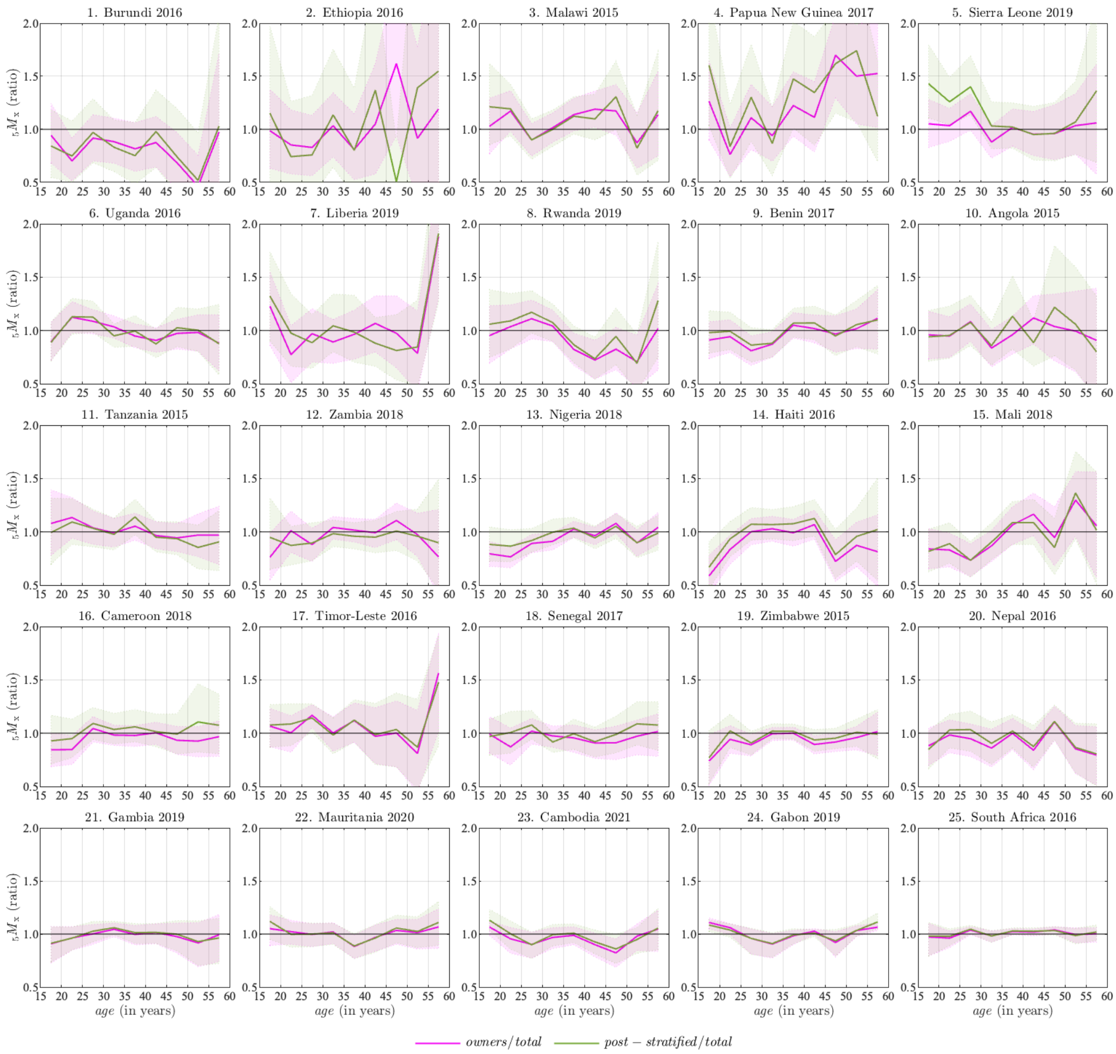
From Figure 2 we also note that adult mortality estimates derived from the subsample of MPOs are comparable to those for the entire sample of female respondents, with statistically significant differences in only five out of the 25 surveys (Burundi, Papua New Guinea, Rwanda, Haiti and Zimbabwe). In Papua New Guinea, the $_{45}q_{15}$ estimate using data from MPOs is biased upwards; in the other three countries, the estimates are lower than in the entire sample. Downwards bias in probability of dying in adulthood was most pronounced in Burundi (0.80; 95%-CI: 0.65-0.96); which is where MPO was the lowest.

In the remaining 19 countries, the ratio of the ${}_{45}q_{15}$ is never greater than 1.1 or smaller than 0.9 and does not reach statistical significance.

The second observation from Figure 2 is that adult mortality estimates after post-stratification weighting are generally close to pre-adjustment estimates. In the four DHS (Burundi, Rwanda, Haiti and Zimbabwe) where the estimates based on MPOs are biased downwards, post-stratification leads to an upwards adjustment that renders the difference insignificant, even though the point-estimate sometimes still shows a considerable downward bias. In four countries (Sierra Leone, Tanzania, Cameroon and Senegal), the ratio of ${}_{45}q_{15}$ after post-stratification is further removed from 1 than the estimate before post-stratification weighting, though it remains statistically indifferent from the total population estimate.

Figure 3 summarizes age-specific mortality rate ratios. Because countries are arranged by female MPO prevalence, this illustration shows that estimates stabilize as MPO prevalence increases. In countries where MPO prevalence is lower, the ratios are more erratic, and that is particularly the case at both ends of the age-spectrum, i.e., below age 25 and above age 45. In some instances, post-stratification weighting produces a correction in the expected direction (e.g., Senegal and Zimbabwe), but in several other countries the correction induced by the post-stratification weights are erratic (e.g., Ethiopia and Sierra Leone). Uncertainty bound around estimates are also higher at younger and older ages, which is related to the lower effective sample size (i.e., number of siblings) for estimating mortality.

Figure 3: Ratio of age-specific mortality rates (nMx) among mobile phone owners relative to the total sample before and after post stratification, by country (25 DHS surveys).



This figure illustrates the ratio of nMx derived from reports from mobile phone owners relative to the total sample, from 2500 bootstrapped samples across 25 surveys. It presents two distinct estimates: in pink, the ratio of mobile phone owners estimate weighted according to Demographic and Health Surveys (DHS), relative to the total sample, and in green, the ratio of the mobile phone owners estimate adjusted by post-stratification weights. The post-stratification weights have been calculated based on the total sample distribution of age, type and region of residence, education level, wealth above or below the mean, and household size. Surveys are sorted from left to right by MPO

Discussion

Mobile phone surveys are increasingly considered as alternatives for classical face-to-face data collection in LMICs and are particularly appealing in situations where timely data are needed, or in-person data collection is restricted or considered too costly. MPO is, however, unequally distributed and this may introduce sample selection bias whenever mobile phone samples are generated via random digit dialing (Sánchez-Páez et al., 2023). In this study, we evaluated bias in adult mortality estimates from the from SSH by comparing estimates from a general population sample with those from a subsample of mobile phone owners. To that end, we used data from 25 DHS in LMICs that included information on MPO and collected SSH.

In many countries, MPO among women remains low, and in four, the rates were below 40%. The higher prevalence of MPO among male respondents compared to their female counterparts is pertinent for mortality measurement if SSH are administered to women.

In addition, MPO was selective with respect to several sociodemographic characteristics (age, sex, education, marital status, place of residence (urban/rural), region, and household wealth and size). The association of MPO with education, wealth and place of residence and household size was consistent across surveys, which was not the case for marital status. We also note substantial regional variation in MPO, with respondents residing in the capital regions often having higher odds of owning a mobile phone.

Overall, MPO-associated selection bias in summary indices of adult mortality (e.g., ${}_{45}q_{15}$) are generally modest, and exceeded 10% in only five out of the 25 countries that were included in this study. In one of these countries (Papua New Guinea), adult mortality was even higher in the data derived from the subsample of mobile owners. In the countries where bias was statistically significant, this was usually alleviated -and no longer statistically significant- after post-stratification weighting using socio-demographic attributes of the respondents. These corrections were, however, small and fall short of recovering the point estimate for the general population sample. The assessment of MPO-associated selection bias in adult mortality estimates from SSH is therefore quite different from the one observed for under-five mortality (U5M) from birth histories (Sánchez-Páez et al., 2023). We hypothesize that this is due to the fact that the correlation between mother's background characteristics and her children's mortality risks is greater than the association between the respondent's attributes and the mortality risk of her adult siblings. This implies that corrections for this bias via post-stratification weighting on the respondent's background characteristics will be less potent.

The age-disaggregated estimates also suggest that the largest differences between estimate from mobile phone owners and the general population sample arise from mortality estimates at both ends of the age spectrum, where the statistical uncertainty is greatest and mobile phone ownership is lower. Summary indices of adult mortality derived from mobile phone surveys will therefore be less prone to possible bias when restricted to mid-adulthood (e.g., ${}_{30}q_{20}$). This conclusion adds to the more general observation that SSH data for older adults are less reliable due to errors in the reporting of ages and ages at death (Helleringer et al, 2014).

To the best of our knowledge, this is the first study to investigate the potential selection bias in adult mortality estimates from sibling survival histories collected in a sample of mobile phone owners. Our study is limited in the sense that MPO was used as a proxy for reaching people in a mobile phone survey, but this does not address other characteristics of mobile phone interviews with possible repercussions for data quality and the ensuing estimates. Non-response, missing observations, and reporting errors are common in face-to-face surveys, and they may be exacerbated in MPS, especially if these are also correlated with the covariates associated with mobile phone ownership (e.g wealth and education) (Helleringer et al., 2023).

In conclusion, adopting MPS in Low-and-Middle-Income Countries (LMICs) offers opportunities and challenges. Our study demonstrates that sample selection bias in adult mortality estimates among Mobile Phone Owners MPOs is likely limited, especially in populations with high MPO rates. However, correcting this bias using post-stratification weights based on respondents' sociodemographic characteristics may be less effective. Our findings complement an earlier study on MPO-related selection bias in under-five mortality and fertility estimates, emphasizing that both sample selection bias and the utility of post-stratification weighting depend on the specific demographic indicator being examined.

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