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Supplementary appendix

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Supplementary Results Appendix

Women's risk of death beyond 42 days postpartum: a pooled analysis of longitudinal Health and Demographic Surveillance System data in sub-Saharan Africa

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Table of Contents

A. Risk of death 42-122 days postpartum over time, by five-year childbirth cohort

Descriptive statistics indicate that there was a decline in postpartum pregnancy-related mortality from about 4/1000 to 2/1000 from the 1991-95 cohort and the 2016-20 cohort. This could indicate either declining risk, heterogeneity in the sample, or both.

We analysed the ratio of childbirths to deaths within the interval 42-122 days for each cohort in the HDSS sample. The 95% confidence intervals were calculated using bootstrapping of 1000 resamples. There is evidence of a statistically significant lower risk of death for the 2006-10 cohort onwards, which may reflect changing mortality conditions as indicated by the multivariable regression results but may also be affected by heterogeneity in the sample.

Table S5. Risk of death 42-122 days over time, by five-year childbirth cohort

Childbirth cohort	Total childbirths	Died 42-122 days	Ratio per 1000	95% CI lower	95% CI upper
1991-95	20284	17	0.84	0.50	1.24
1996-00	47543	38	0.81 0·80	0.55	1.06
2001-05	81801	71	0.87	0.69	1.08
2006-10	182733	100	0.55	0.46	0.65
2011-15	271458	115	0.42	0.35	0.51
2016-20	43285	17	0.39	0.24	0.63

B. Comparison of unadjusted and adjusted death distributions

The distribution of deaths by days since childbirth was adjusted to correct for the overestimation of days until death when calculated using calendar days, (e.g., a woman who survived less than 24 hours but who died on the next calendar day would be misattributed to day 1), splitting deaths between the calendar day of occurrence and the day before. This shifts the density of deaths towards earlier postpartum intervals.

The univariable and multivariable analyses are run on the adjusted distribution.

Table S3 Comparison of unadjusted and adjusted death distributions

Interval	Death Distribution	Person-years	Crude Death Rate (M_x) (per 1000 person-years)
Unadjusted			
0 to 1 day	283	3548·2	79·8
2 to 6 days	136	8858·5	15·4
7 to 13 days	105	12379·1	8·5
14 to 41 days	229	49243·4	4·7
42-122 days	360	139665·9	2·6
4 to 11 months	859	388164·4	2·2
[12 to 18 months]	574	262877·7	2·2
Adjusted			
0 to 1 day	306	3541·0	86·6
2 to 6 days	118	8840·6	13·4
7 to 13 days	101	12354·2	8·2
14 to 41 days	223	49144·5	4·5
42-122 days	363	139386·8	2·6
4 to 11 months	856	388903·1	2·2
[12 to 18 months]	574	263591·7	2·2

C. Hazard of death by time since delivery

We used the hazard of death by time since delivery to choose the risk interval cut points for the Piecewise Constant Hazard model. The figures below (**Figure S1** & **Figure S2**) show the death rates, smoothed using a non-parametric p-spline, for the first 42-days and the first year postpartum. The hazard is exponentially decreasing, and has reached a relatively low level by 42-days postpartum.

Figure S1 Death rate by time since delivery (up to 42-days)

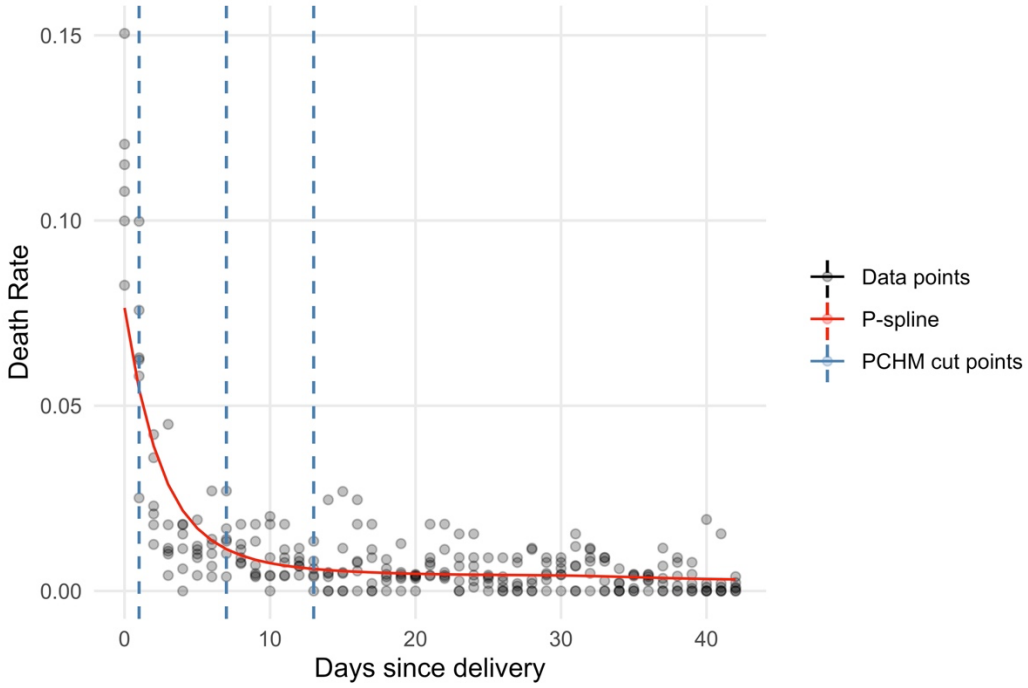
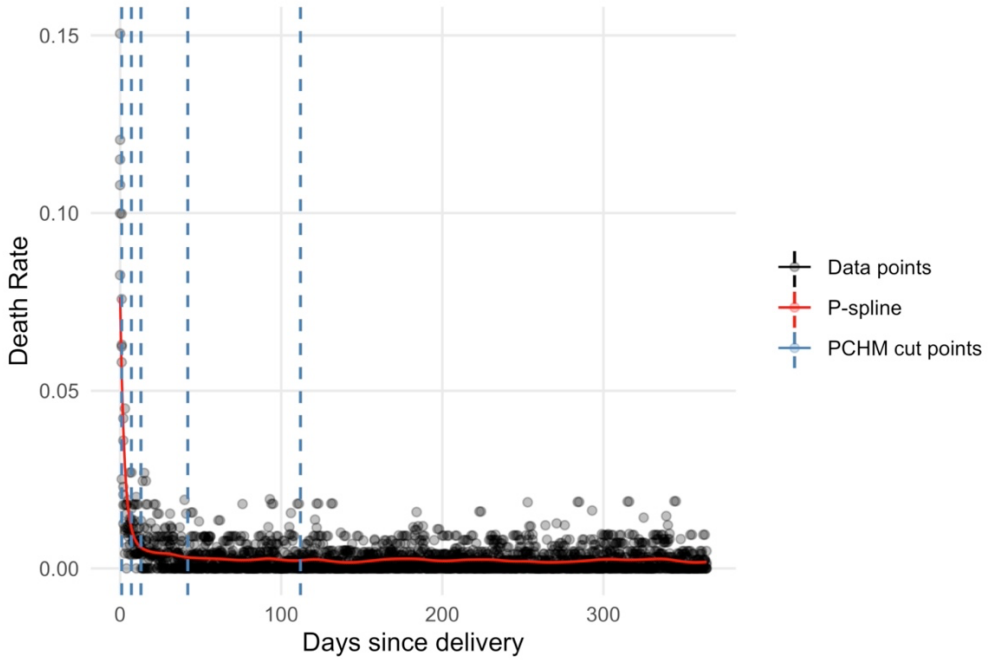


Figure S2 Death rate by time since delivery (up to one year)



D. Calculation of the postpartum Pregnancy-Related Mortality Ratio (PRMR)

The PRMR would conventionally be calculated as the number of pregnancy-related deaths divided by the number of live births, multiplied by 100 000. We are unable to restrict the denominator to live births, but we approximate this as the number of postpartum pregnancy-related deaths divided by the number of births, multiplied by 100 000.

We summed the total deaths occurring within 42 days (748), the total deaths within four-months (1111) and divided these by the total number of births: 647 104. This yields 116 per 100,000 and 174 per 100,000, respectively. To calculate the percentage increase, we then took the natural logarithm of the two, to adjust for the sensitivity of the denominator in the fraction: $ln\left(\frac{174}{116}\right)$ = 40%.

We also calculated the percentage increase in the PRMR implied by a four-month postpartum threshold by estimating a life table with the adjusted death distribution. This yields the same result:

Table S4. Life Table using adjusted death distribution

x	n(days)	n(years)	d	nLx	nMx	lx	dx
0	2	0.00548	306	3541.0	0.0864	100000.0	47.3
2	5	0.0137	118	8840.6	0.0134	99952.6	18.3
7	7	0.0192	101	12354.2	0.00818	99934.4	15.3
14	28	0.0767	223	49144.5	0.00454	99918.7	34.8
42	81	0.222	363	139386.8	0.00260	99883.9	57.7
123	242	0.663	856	388903.1	0.00220	99826.2	145.6
365	182.875	0.501	573	263591.7	0.00217	99680.7	108.5
547.875						99572.2	

$$PRMR\ (0-41days) = \sum_{x=0}^{x=14} dx$$

$$= 116$$

$$PRMR\ (0-122\ days) = \sum_{x=0}^{x=42} dx$$

$$= 174$$

% increase in the postpartum PRMR = $ln\left(\frac{174}{116}\right)$

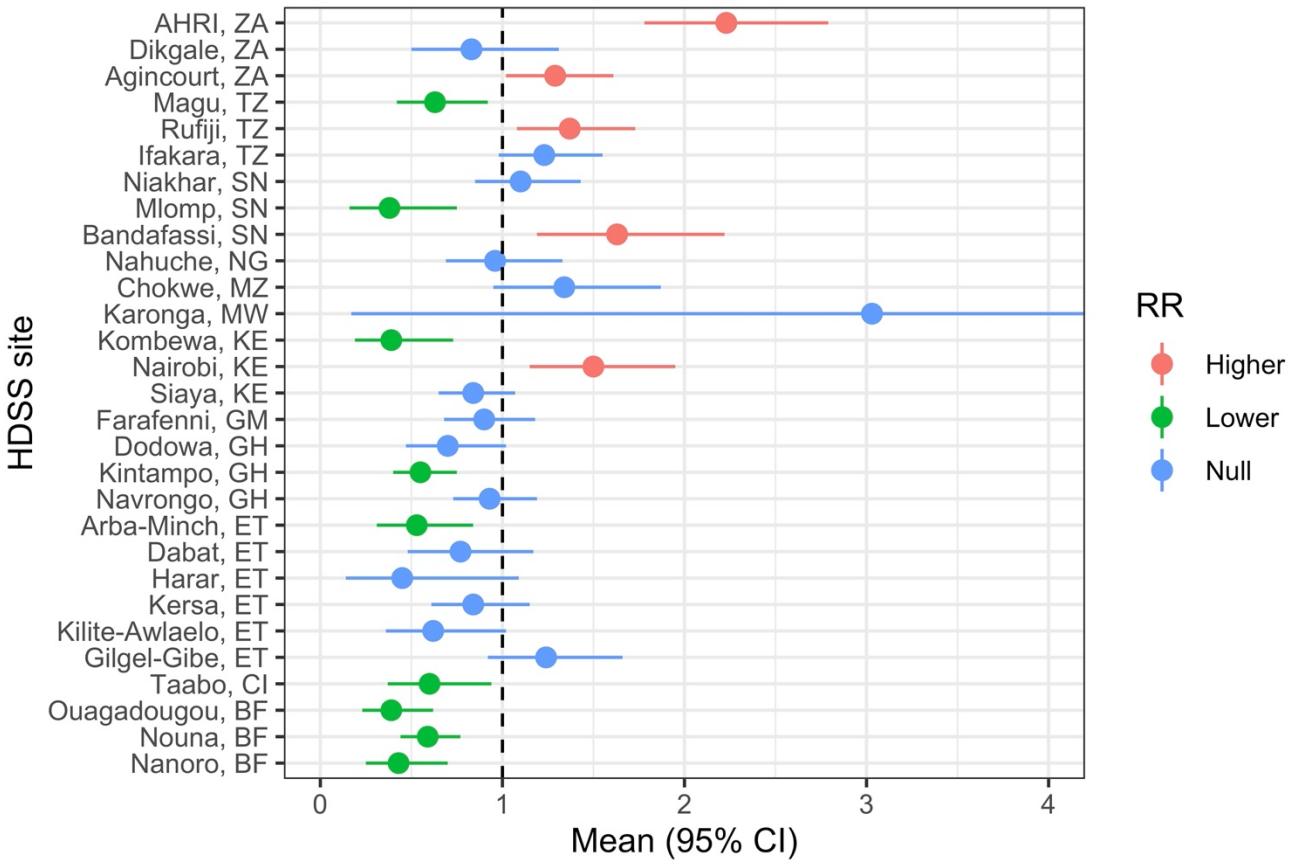
= 40%

E. Main model HDSS site heterogeneity: aggregate-level fixed effects

The main model used aggregate-level fixed effects to control for heterogeneity between HDSS site. Since the model weights the death counts by the person-years exposure for each dummy variable, the effect sizes are independent of population size. The reference category was Basse (The Gambia), since Basse HDSS had the most deliveries. Wald test of joint significance confirmed that aggregate-level fixed effects for HDSS site were significant.

Figure S3 shows the risk ratios for each HDSS site. In total, nine sites had a lower risk of death, relative to Basse. Only five sites had an increased risk of death, in four countries – South Africa, Tanzania, Kenya and Senegal.

Figure S3 Risk ratio of death by HDSS site: aggregate-level fixed effects



ZA = South Africa, TZ = Tanzania, SN = Senegal, NG = Nigeria, MZ = Mozambique, MW = Malawi, KE = Kenya, GM = The Gambia, GH = Ghana, ET = Ethiopia, CI = Cote d'Ivoire, BF = Burkina Faso
Upper CI for Karonga, Malawi (13.58) not displayed.

F. Sensitivity Tests

i. Choice of postpartum risk interval beyond 42 days

Given the lack of consistency between studies in the choice of the risk period beyond 42 days, we incrementally increased the risk period by an additional week to test the sensitivity of the effect size to the choice of the interval.

Table S1 shows the coefficient estimates for the risk intervals in the multivariable model, in two week increments from up to 8 weeks to up to four months. The shorter the risk interval beyond 42 days, the higher the risk of death, relative to the baseline period 12-18 months postpartum (except for 42 days to 12 weeks). This trend of a decrease in the risk of death as the interval lengthens strengthens the case that the risk of death is not constant at pre-pregnancy levels by 42 days.

Table S1 Sensitivity of the multivariable results to the length of the risk interval from 43 days onwards, interval coefficients only

	42 days to 8 weeks		**42 days to 10 weeks**		**42 days to 12 weeks**		**42 days to 14 weeks**		**42 days to 4 months (final model)**	
Variable	*Rate Ratio*	*P-value*	*Rate Ratio*	*P-value*	*Rate Ratio*	*P-value*	*Rate Ratio*	*P-value*	*Rate Ratio*	*P-value*
Interval										
0-1 day	**38·80**	<0·0001	**38·76**	<0·0001	**38·79**	<0·0001	**38·81**	<0·0001	**38·82**	<0·0001
2-6 days	**4·97**	<0·0001	**4·97**	<0·0001	**4·97**	<0·0001	**4·97**	<0·0001	**4·97**	<0·0001
7-13 days	**3·35**	<0·0001	**3·35**	<0·0001	**3·35**	<0·0001	**3·35**	<0·0001	**3·35**	<0·0001
14-41 days	**2·06**	<0·0001	**2·06**	<0·0001	**2·06**	<0·0001	**2·06**	<0·0001	**2·01**	<0·0001
42 days to X[1] weeks	**1·31**	0·041	**1·29**	0·012	**1·21**	0·031	**1·27**	0·0041	**1·20**	0·016
X[1]-365 days	1·06	0·33	1·05	0·40	1·06	0·36	1·03	0·64	1·02	0·76
12-17 months (reference)	1·0		1·0		1·0		1·0		1·0	

[1] X increases incrementally from 8 weeks in the left-most column to 4 months in the final model.

ii. Choice of baseline period

The choice of the baseline period used to proxy women's background risk of death differs between studies, with little consistency. While our main results depend on an assumed baseline period of 12-17 months postpartum, we re-ran our multivariable model with two alternate choices of baseline period: 12-23 months, and 12-35 months postpartum. The results of these models are presented in **Table S2.**

The risk for the period 42-122 days postpartum remains elevated in both models, although the effect size decreases slightly as the baseline period lengthens. Relative to a baseline of 12-23 months, the risk is 17% higher between 42-122 days; relative to a baseline of 12-35 months, the risk is 15% higher. In both models, the effects are significant at 95% confidence.

Table S2. Sensitivity of the multivariable results to the baseline risk period

	Multivariable with baseline 12-24 months			Multivariable with baseline 12-36 months		
Variable	*Rate Ratio*	*95% CI*	*P-value*	*Rate Ratio*	*95% CI*	*P-value*
Interval						
0-1 day	37·94	32·85 – 43·70	<0·0001	37·27	32·47 – 42·63	<0·0001
2-6 days	4·88	3·89 – 6·04	<0·0001	4·79	3·84 – 5·90	<0·0001
7-13 days	3·25	2·58 – 4·04	<0·0001	3·19	2·54– 3·95	<0·0001
14-41 days	2·00	1·71 – 2·34	<0·0001	1·96	1·68 – 2·28	<0·0001
42-122 days	1·17	1·02 – 1·33	0·022	1·15	1·01 – 1·30	0·033
4-11 months	0·99	0·89 – 1·10	0·83	0·97	0·88 – 1·07	0·53
Baseline (reference)	1·0			1·0		
Parity (within HDSS)						
1	1·28	1·16 – 1·40	<0·0001	1·24	1·14 – 1·35	<0·0001
2-3 (reference)	1·0			1·0		
4-6	0·89	0·75 – 1·05	0·18	0·85	0·73 – 0·98	0·035
7+	0·72	0·49 – 1·04	0·072	0·78	0·57 – 1·08	0·13
Age group						
<15	0·92	0·55 – 1·43	0·74	0·82	0·51 – 1·24	0·39
15-24	0·64	0·58 – 0·71	<0·0001	0·65	0·59 – 0·71	<0·0001
25-34 (reference)	1·0			1·0		
35+	1·33	1·20 – 1·48	<0·0001	1·31	1·19 – 1·44	<0·0001
Cohort						
1991-1995	0·94	0·75 – 1·19	0·61	0·94	0·76 – 1·16	0·56
1996-2000 (reference)	1·0			1·0		
2001-2005	0·98	0·84 – 1·15	0·80	0·96	0·83 – 1·10	0·56
2006-2010	0·82	0·70 – 0·96	0·012	0·79	0·68 – 0·91	0·00078
2011-2015	0·70	0·60 – 0·82	<0·0001	0·66	0·57 – 0·77	<0·0001
2016-2020	0·63	0·48 – 0·82	<0·0001	0·58	0·45 – 0·75	<0·0001

G. Date Heaping

Figure S4 and **Figure S5** show the frequency of dates recorded for delivery date (child DOB) and for date of death (for women who have delivered in the past 18 months), respectively. Both dates are badly affected by heaping. For the date of delivery, across all months, the 15th of the month is significantly more common than any other date, followed by the 1st of the month. This suggests that in some sites, imputing the mid-point of the month when the precise date is unknown is standard practice, while for other sites, the first day of the month is used. For the date of maternal death, the 16th of the month is the most common, followed by the 15th. This again suggests that date imputation to the middle of the month is common. As the delivery event is most likely to be recorded as the 15th, if the mother dies the following calendar day, this explains why the 16th of the month is so frequently recorded for the maternal date of death.

June is the most frequently recorded month for delivery date, while March is the most common for the maternal date of death. While this is suggestive of date imputation, the effect of heaping is difficult to disentangle from genuine seasonality in deliveries and deaths.

Figure S4. HDSS Data Date Heaping: Delivery Date

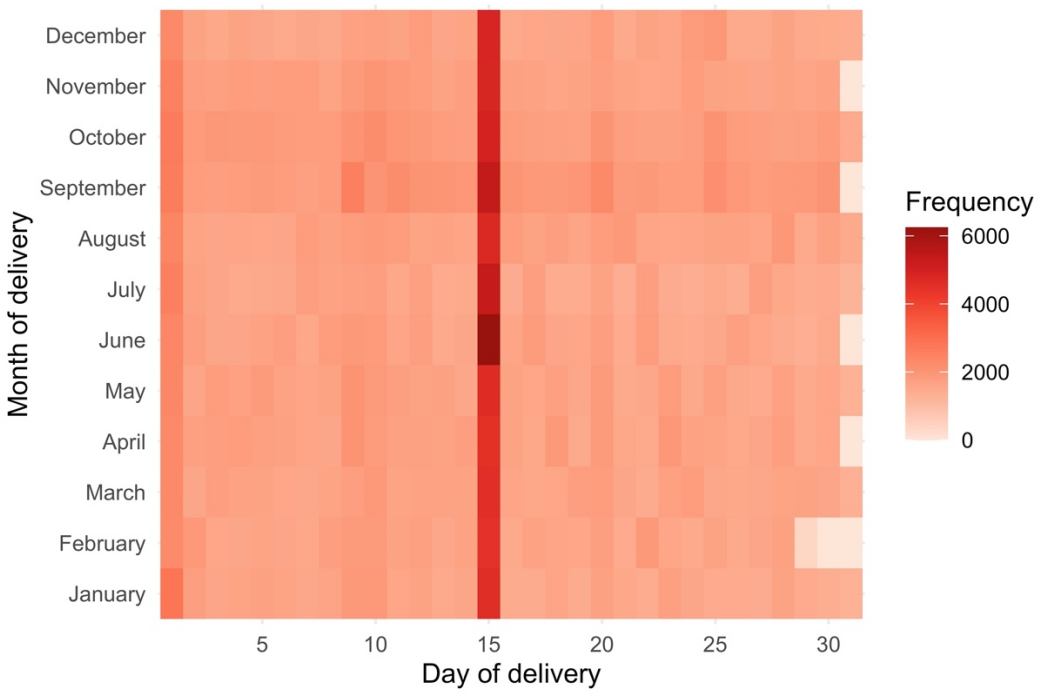


Figure S5. HDSS Data Date Heaping: Date of Maternal Death