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Nonparametric Estimation of Survivorship Function using Retrospective Data on Duration of Breastfeeding-A Smoothing Technique

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Abstract: Retrospectively reported data on duration of breastfeeding often exhibit concentration of points at multiples of 6 or 12 months. As a result, the estimated survivorship function shows jumps at these points. Appropriate statistical methods are necessarily called for obtaining the smooth estimates of the curve. A nonparametric regression smoother, popularly known as loess (locally weighted linear regression smoother has been used here to obtain the smooth estimates. The proposed method is applied to duration data of the 6 states of North East India.

Key words: Survivorship function, smooth estimates, nonparametric regression smoother, loess, India

INTRODUCTION

An impressive body of evidence suggests that breastfeeding has nontrivial beneficial effects on the health and survival during infancy and early childhood. Breastfeeding not only gives immunological protection to an infant against early morbidity and mortality but also offers contraceptive protection to mothers against closely spaced pregnancies (Nath *et al*., 1994; Nath and Goswami, 1997). Breastfeeding is universal in most societies. However, the length of duration of breastfeeding varies across societies depending on their social, economic and demographic factors (Aaryal, 2004). Efforts of government and non government organizations to improve duration of breastfeeding has shown effective in the developing countries including India (Chakrabarty and Singh, 2005).

Analysis and estimation of duration of breastfeeding are often based on current status method which lacks retrospective information on breastfeeding. Retrospective information on duration of breastfeeding depends sharply on mothers power of recall. It is often found that these retrospectively reported duration often exhibit heaping or jumps at certain points, such as multiples of 6 or 12 months. As a result, the survivorship curve shows jumps at these points of concentration. In this study, an attempt has been made to reduce the bias arising out of the recall or reporting bias by applying a technique to smoothen the survivorship function. The method is then employed to estimate the nonparametric survivorship functions along with median durations with data collected in the National Family Health Surveys in the 6 North East states of India viz. Arunachal, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.

MATERIALS AND METHODS

The first National Family Health Survey (NFHS-1) in the 6 small North-Eastern states of India (Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh and Tripura) conducted during February to June, 1993 gathered information on a representative sample of 6266 ever-married women aged 13-49 (IIPS, 1995). The second round of the survey, NFHS-2 conducted during May, 1999 to June, 2000 gathered information on 6467 ever-married women aged 15-49 (IIPS and ORC Macro, 2000). Information of breastfeeding was collected for the children of interviewed women born in the 4 years preceding the survey in NFHS-1 and 3 years preceding NFHS-2. For any given woman, a maximum of 3 births are included in the analysis for NFHS-1 whereas a maximum of only 2 births are included in the analysis of NFHS-2. For a total of 3525 children information on breastfeeding duration were collected for NFHS-1 of whom 1914 cases were still breastfeeding at the date of interview or have breastfed until the child died. For NFHS-2, information on duration of breastfeeding on a total of 2792 children were collected of whom 2052 cases were still breastfeeding at the date of interview or have breast-fed their child until died. The rest of the children completed their breastfeeding.

Loess smoothing: Let $\hat{S}(t_0)$ be the unsmooth Kaplan and Meier (1958) or Nelson-Aalen (Aalen, 1978) estimate of the survivorship function at time t_0. Let $N_s(t_0)$ represent a neighborhood of t_0, comprising of k nearest neighbors of t_0 with respect to the smoothing parameter s to be referred herein as span. Define:

$$\Delta(t_0) = \max_{t \in N_s(t_0)} |t_0 - t| \quad (1)$$

Assign weights to each t in N_s (t_0) using tricube weight function:

$$W_s(t_0, t) = w\left(\frac{|t_0 - t|}{\Delta(t_0)}\right) \quad (2)$$

Where:

$$w(u) = \begin{cases} (1-u^3)^3 & \text{for } 0 \le u < 1 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

The loess procedure fits a locally weighted linear regression by solving a separate weighted least squares problem at each target point t_0:

$$\min_{\alpha(t_0), \beta(t_0)} \sum_{t \in N_s(t_0)} W_s(t_0, t)\left\{\hat{S}(t) - \alpha(t_0) - \beta(t_0)t\right\}^2 \quad (4)$$

The smooth estimate of $\hat{S}$ (t_0) at time t_0, written as $\hat{S}$ (t_0) is then obtained as:

$$\bar{S}(t_0) = \hat{\alpha}(t_0) = \hat{\beta}(t_0)t_0 \quad (5)$$

Where $\hat{\alpha}(t_0)$ and $\hat{\beta}(t_0)$ are the solutions of Eq. 4. The smoothing parameters has been so selected to minimize the estimated cross validation function:

$$CV(s) = \sum_t \left(\hat{S}(t) - \bar{S}_0(t/s)\right)^2 \quad (6)$$

Where, $\bar{s}_0(t/s)$ is the leave-one-out smooth at t that is $\bar{s}_0(t/s)$ is constructed using all points (t, $\hat{S}$ (t)) except (t_0, $\hat{S}$ (t_0) and the resultant local least squares line is evaluated at t thereby giving $\bar{s}_{(0)}(t/s)$. Omitting (t_0, $\hat{S}$ (t_0)) makes the fitted value $\bar{s}_{(0)}(t/s)$ independent of $\hat{S}$ (t_0). It can be shown that:

$$V(s) = \sum_t \left\{\frac{\hat{S}(t) - \bar{S}(t/s)}{1 - s_{ii}}\right\}^2 \quad (7)$$

Where s_{ii} is the ith diagonal element of the nxn smoother matrix S. A 95% confidence interval for S (t) based on the smooth estimates under the assumption of normally distributed errors or a sufficiently large sample is approximately:

$$\bar{S}(t_0) \pm 1.96\sqrt{\hat{V}\left(\bar{S}(t_0)\right)} \quad (8)$$

It can be shown that the variance-covariance matrix of the smooth estimates $\bar{s}$ is given by $\sum(\bar{s}) = \sigma^2 SS'$ where S is n×m smoother matrix as earlier and σ^2 is the common conditional variance estimated as:

$$\frac{\sum e_t^2}{tr(S)} \text{ for } e_t = \hat{S}(t) - \bar{S}(t)$$

RESULTS

Researchers have applied the theory discussed in the preceding sections of univariate analysis of duration data to the duration of breastfeeding collected through NFHS-1 and NFHS-2 for the 6 North-Eastern states of India. Here the event of interest is the termination of breastfeeding and thereby the duration is the number of months the child was being breastfed. If in case the child is still breastfeeding at the time interview or was breastfed until death then the observed duration is called a censored duration.

Researchers present the survival probability estimates (Kaplan-Meier and Nelson-Aalen) along with their 95% confidence intervals for both NFHS-1 and NFHS-2 through Table 1-4. The smooth estimates are also

Table 1: Survival probability estimates (Kaplan-Meier), NFHS-1

	Kaplan-Meier estimates			Smooth estimates		
Time	K-M estimates	95% lower CI	95% upper CI	Smooth	95% lower CI	95% upper CI
0	0.998	0.997	0.999	0.999	0.974	1.024
1	0.992	0.989	0.995	0.993	0.973	1.012
2	0.986	0.982	0.990	0.986	0.970	1.002
3	0.980	0.976	0.985	0.980	0.966	0.993
4	0.975	0.970	0.980	0.973	0.959	0.986
5	0.971	0.965	0.976	0.964	0.950	0.978
6	0.958	0.951	0.965	0.952	0.938	0.966
7	0.950	0.942	0.957	0.936	0.921	0.950
8	0.926	0.916	0.935	0.914	0.900	0.928
9	0.892	0.881	0.904	0.884	0.870	0.898
10	0.866	0.854	0.879	0.845	0.831	0.859
11	0.848	0.835	0.861	0.802	0.788	0.816
12	0.717	0.700	0.734	0.756	0.742	0.770
13	0.693	0.675	0.710	0.711	0.697	0.725
14	0.654	0.636	0.672	0.668	0.654	0.682
15	0.626	0.607	0.644	0.631	0.617	0.645
16	0.598	0.579	0.617	0.601	0.586	0.615
17	0.590	0.571	0.609	0.572	0.558	0.586
18	0.523	0.503	0.543	0.547	0.533	0.562
19	0.515	0.495	0.535	0.527	0.513	0.541
20	0.496	0.476	0.517	0.508	0.494	0.522
21	0.494	0.475	0.515	0.487	0.473	0.501
22	0.489	0.469	0.510	0.461	0.447	0.475
23	0.486	0.466	0.506	0.435	0.421	0.449
24	0.362	0.342	0.384	0.408	0.394	0.422
25	0.356	0.336	0.378	0.384	0.370	0.398
26	0.346	0.325	0.368	0.361	0.347	0.375
27	0.343	0.322	0.365	0.345	0.331	0.360
28	0.339	0.319	0.361	0.334	0.320	0.348
29	0.337	0.316	0.359	0.326	0.312	0.340
30	0.305	0.284	0.328	0.317	0.303	0.331
31	0.305	0.284	0.328	0.309	0.295	0.323
32	0.299	0.278	0.322	0.302	0.288	0.316
33	0.298	0.277	0.321	0.293	0.279	0.307
34	0.293	0.271	0.316	0.285	0.271	0.299
35	0.292	0.270	0.315	0.274	0.260	0.288

Table 1: Continue

	Kaplan-Meier estimates			Smooth estimates		
Time	K-M estimates	95% lower CI	95% upper CI	Smooth	95% lower CI	95% upper CI
36	0.245	0.222	0.271	0.264	0.250	0.278
37	0.245	0.222	0.271	0.255	0.241	0.269
38	0.241	0.218	0.267	0.247	0.233	0.261
39	0.241	0.218	0.267	0.242	0.228	0.256
40	0.241	0.218	0.267	0.239	0.225	0.253
41	0.241	0.218	0.267	0.236	0.222	0.250
42	0.231	0.206	0.258	0.233	0.219	0.247
43	0.227	0.202	0.255	0.231	0.217	0.245
44	0.227	0.202	0.255	0.229	0.215	0.243
45	0.227	0.202	0.255	0.227	0.212	0.241
46	0.227	0.202	0.255	0.224	0.210	0.238
47	0.227	0.202	0.255	0.222	0.208	0.236
48	0.216	0.185	0.252	0.220	0.206	0.234
49	0.216	0.185	0.252	0.218	0.204	0.232
50	0.216	0.185	0.252	0.217	0.203	0.231
51	0.216	0.185	0.252	0.216	0.200	0.232
52	0.216	0.185	0.252	0.215	0.195	0.235
53	0.216	0.185	0.252	0.214	0.189	0.239

Table 2: Survival probability estimates (Nelson-Aelen) NFHS-1

	Nelson-Aalen estimates			Smooth estimates		
Time	N-A estimates	95% lower CI	95% upper CI	Smooth	95% lower CI	95% upper CI
0	0.998	0.997	0.999	0.999	0.976	1.022
1	0.992	0.989	0.995	0.993	0.974	1.011
2	0.986	0.982	0.990	0.986	0.972	1.001
3	0.980	0.976	0.985	0.980	0.967	0.992
4	0.975	0.970	0.980	0.973	0.960	0.985
5	0.971	0.965	0.976	0.964	0.951	0.977
6	0.958	0.951	0.965	0.952	0.939	0.965
7	0.950	0.942	0.957	0.936	0.923	0.949
8	0.926	0.917	0.935	0.915	0.902	0.928
9	0.893	0.882	0.905	0.886	0.873	0.899
10	0.868	0.855	0.880	0.848	0.835	0.861
11	0.849	0.836	0.862	0.807	0.794	0.820
12	0.728	0.711	0.745	0.763	0.750	0.776
13	0.704	0.686	0.721	0.720	0.707	0.733
14	0.665	0.647	0.684	0.678	0.665	0.691
15	0.637	0.619	0.656	0.643	0.630	0.656
16	0.609	0.590	0.629	0.613	0.600	0.626
17	0.601	0.582	0.621	0.584	0.571	0.597
18	0.537	0.517	0.558	0.560	0.547	0.573
19	0.528	0.508	0.549	0.540	0.527	0.553
20	0.510	0.489	0.531	0.522	0.509	0.535
21	0.508	0.488	0.529	0.502	0.489	0.515
22	0.503	0.482	0.524	0.478	0.465	0.490
23	0.499	0.479	0.520	0.453	0.440	0.466
24	0.387	0.365	0.410	0.428	0.415	0.441
25	0.381	0.359	0.404	0.406	0.393	0.418
26	0.370	0.348	0.393	0.384	0.371	0.397
27	0.367	0.344	0.390	0.369	0.356	0.382
28	0.363	0.341	0.386	0.357	0.344	0.370
29	0.360	0.338	0.384	0.349	0.336	0.362
30	0.327	0.305	0.352	0.340	0.327	0.353
31	0.327	0.305	0.352	0.332	0.319	0.345
32	0.322	0.299	0.346	0.324	0.312	0.337
33	0.320	0.297	0.345	0.316	0.303	0.328
34	0.315	0.292	0.340	0.307	0.294	0.320
35	0.313	0.290	0.338	0.296	0.283	0.309
36	0.267	0.242	0.295	0.286	0.273	0.299
37	0.267	0.242	0.295	0.277	0.264	0.290
38	0.263	0.238	0.291	0.269	0.256	0.282
39	0.263	0.238	0.291	0.264	0.251	0.277
40	0.263	0.238	0.291	0.260	0.247	0.273

Table 2: Continue

	Nelson-Aalen estimates			Smooth estimates		
Time	N-A estimates	95% lower CI	95% upper CI	Smooth	95% lower CI	95% upper CI
41	0.263	0.238	0.291	0.258	0.245	0.271
42	0.252	0.225	0.282	0.255	0.242	0.268
43	0.248	0.220	0.279	0.252	0.239	0.265
44	0.248	0.220	0.279	0.250	0.237	0.263
45	0.248	0.220	0.279	0.247	0.234	0.260
46	0.248	0.220	0.279	0.245	0.232	0.258
47	0.248	0.220	0.279	0.243	0.230	0.256
48	0.236	0.202	0.275	0.241	0.228	0.254
49	0.236	0.202	0.275	0.239	0.226	0.252
50	0.236	0.202	0.275	0.237	0.225	0.250
51	0.236	0.202	0.275	0.236	0.222	0.251
52	0.236	0.202	0.275	0.235	0.217	0.253
53	0.236	0.202	0.275	0.234	0.211	0.257

Table 3: Survival probability estimates (Kaplan-Meier), NFHS-2

	Kaplan-Meier estimates			Smooth estimates		
Time	K-M estimates	95% lower CI	95% upper CI	Smooth	95% lower CI	95% upper CI
0	0.999	0.997	1.000	0.999	0.977	1.020
1	0.995	0.992	0.998	0.993	0.978	1.009
2	0.986	0.981	0.990	0.988	0.976	1.001
3	0.982	0.977	0.987	0.983	0.969	0.997
4	0.979	0.973	0.984	0.979	0.965	0.992
5	0.976	0.970	0.982	0.974	0.961	0.988
6	0.970	0.963	0.977	0.969	0.955	0.983
7	0.963	0.956	0.971	0.961	0.948	0.975
8	0.953	0.945	0.962	0.952	0.938	0.965
9	0.941	0.931	0.951	0.941	0.927	0.954
10	0.927	0.917	0.938	0.922	0.909	0.936
11	0.919	0.908	0.931	0.892	0.878	0.906
12	0.836	0.820	0.852	0.856	0.842	0.870
13	0.818	0.801	0.835	0.816	0.803	0.830
14	0.778	0.759	0.797	0.785	0.771	0.799
15	0.759	0.740	0.779	0.761	0.747	0.774
16	0.737	0.717	0.758	0.735	0.721	0.748
17	0.726	0.705	0.747	0.703	0.689	0.716
18	0.647	0.623	0.671	0.671	0.657	0.684
19	0.637	0.613	0.661	0.641	0.627	0.655
20	0.619	0.595	0.644	0.624	0.610	0.637
21	0.613	0.588	0.638	0.615	0.601	0.628
22	0.609	0.584	0.634	0.600	0.587	0.614
23	0.605	0.580	0.631	0.574	0.560	0.587
24	0.515	0.487	0.544	0.543	0.530	0.557
25	0.507	0.479	0.537	0.515	0.501	0.528
26	0.496	0.467	0.526	0.499	0.486	0.513
27	0.494	0.465	0.524	0.494	0.480	0.507
28	0.489	0.460	0.520	0.489	0.475	0.503
29	0.487	0.457	0.518	0.483	0.470	0.497
30	0.474	0.442	0.507	0.479	0.465	0.492
31	0.474	0.442	0.507	0.475	0.461	0.489
32	0.474	0.442	0.507	0.474	0.460	0.487
33	0.474	0.442	0.507	0.474	0.461	0.486
34	0.474	0.442	0.507	0.474	0.458	0.489
35	0.474	0.442	0.507	0.474	0.452	0.495

shown side by side. In Table 5, researchers present the median duration of breastfeeding along with their 95% confidence intervals for both NFHS-1 and NFHS-2. The median duration of breastfeeding for NFHS-1 is found to be 21 months and it is slightly improved in NFHS-2 with a value of 26 months.

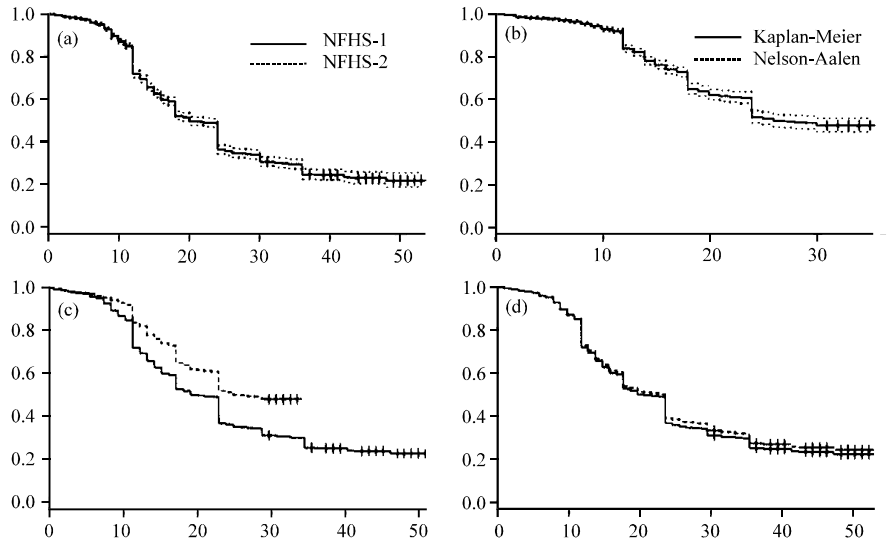

Fig. 1: a) Kaplan-Meier estimate of survival curve along with 95% confidence band for NHFS-1; b) Kaplan-Meier estimate of survival curve along with 95% confidence band for NHFS-2; c) Comparison of Kaplan-Meier estimate for NHFS-1 and NHFS-2; d) Comparison of Kaplan-Meier and Nelson-Aalen for NHFS-1

Table 4: Survival probability estimates (N-A), NFHS-2

	Nelson-Aalen estimates			Smooth estimates		
Time	N-A estimates	95% lower CI	95% upper CI	Smooth	95% lower	95% upper
0	0.999	0.997	1.000	0.999	0.978	1.019
1	0.995	0.992	0.998	0.993	0.979	1.008
2	0.986	0.981	0.990	0.988	0.976	1.000
3	0.982	0.977	0.987	0.983	0.970	0.996
4	0.979	0.974	0.985	0.979	0.966	0.992
5	0.976	0.970	0.982	0.974	0.962	0.987
6	0.970	0.963	0.977	0.969	0.956	0.982
7	0.963	0.956	0.971	0.961	0.949	0.974
8	0.953	0.945	0.962	0.952	0.939	0.965
9	0.941	0.932	0.951	0.941	0.928	0.954
10	0.928	0.917	0.939	0.923	0.910	0.936
11	0.920	0.908	0.931	0.894	0.881	0.907
12	0.840	0.823	0.856	0.859	0.846	0.872
13	0.822	0.805	0.839	0.820	0.808	0.833
14	0.783	0.764	0.802	0.790	0.777	0.802
15	0.764	0.744	0.784	0.766	0.753	0.779
16	0.742	0.722	0.763	0.740	0.727	0.753
17	0.731	0.710	0.752	0.709	0.696	0.722
18	0.655	0.632	0.680	0.678	0.665	0.691
19	0.645	0.621	0.670	0.650	0.637	0.662
20	0.627	0.603	0.653	0.632	0.619	0.645
21	0.621	0.597	0.647	0.623	0.611	0.636
22	0.617	0.592	0.643	0.610	0.597	0.622
23	0.614	0.589	0.640	0.584	0.571	0.597
24	0.528	0.500	0.559	0.555	0.542	0.568
25	0.521	0.492	0.552	0.528	0.515	0.541
26	0.509	0.48	0.541	0.513	0.500	0.526
27	0.507	0.478	0.539	0.507	0.494	0.520
28	0.503	0.473	0.535	0.502	0.489	0.515
29	0.500	0.470	0.532	0.497	0.484	0.510
30	0.487	0.455	0.521	0.492	0.479	0.505
31	0.487	0.455	0.521	0.488	0.475	0.501
32	0.487	0.455	0.521	0.487	0.474	0.500
33	0.487	0.455	0.521	0.487	0.475	0.499
34	0.487	0.455	0.521	0.487	0.472	0.501
35	0.487	0.455	0.521	0.487	0.466	0.507

Table 5: Estimates of median duration and 95% C.I

	K-M estimate		N-A estimate	
Parameters	Estimates (95% CI)	Smooth estimates (95% CI)	Estimates (95% CI)	Smooth estimates (95% CI)
NFHS-1 (n = 3525)	20 (19, 24)	21 (19, 22)	23 (20, 24)	22 (21, 22)
NFHS-2 (n = 2792)	26 (24, NA)	26 (26, 29)	30 (24, NA)	29(27, NA)

In Fig. 1a, b, the Kaplan-Meier survival curves along with their 95% confidence bands are presented for NFHS-1 and NFHS-2, respectively. The right skewness of the distribution are evident from the plots. The plot in Fig. 1a descends sharply between 12 and 24 months and then trails off gradually, reaching its minimum value at about 53 months. The intermediate steep descent shows that for many subjects in NFHS-1 breastfeeding terminated between 12 and 24 months. The relatively long right tail is a result of the few subjects who had long breastfeeding experience. Whereas, the results of NFHS-2 and the corresponding plot in Fig. 1b depicts a difference in which case the curve is less steeper and does not go to zero. This is because of the fact that largest observation was a censored value. Figure 1c shows the comparison of the survival curves for NFHS-1 and NFHS-2 and a longer breastfeeding experience is evident in the later survey, i.e., NFHS-2, the estimated survival curve for NFHS-2 lying completely above NFHS-1. Figure 1d shows the comparison of Kaplan-Meier and Nelson-Aalen survival curves for NFHS-1. The plot suggests that there are differences in the estimates for larger values of t and

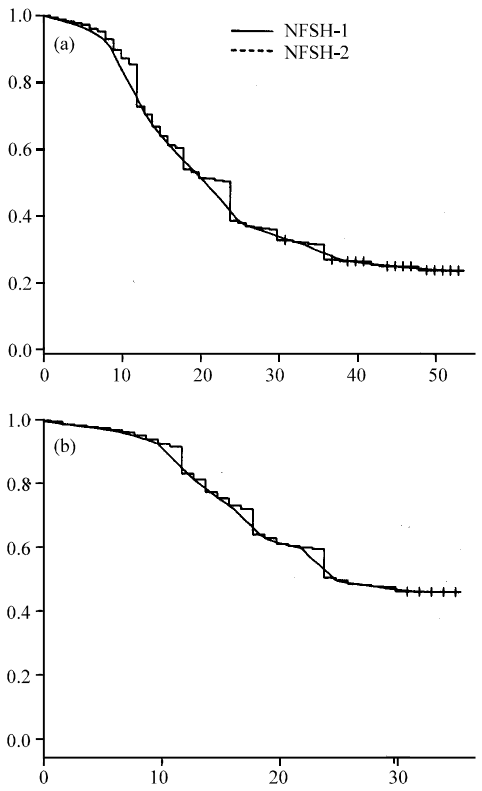

Fig. 2: a) Kaplan-Meier and smooth estimate of survival for NHS-1; b) Kaplan-Meier and smooth estimate of survival curve for NHS-2

Nelson-Aalen estimator of the survival curve is always greater than or equal to Kaplan-Meier estimates. Smooth estimates and the corresponding plots in Fig. 2a, b are obtained by running the S-plus function loess (MathSoft Inc., 1997) with span s = 0.3 and s = 0.2, respectively for NFHS-1 and NFHS-2. These values are arrived at by minimizing the cross validation function in Eq. 7.

RESULTS AND DISCUSSION

The duration of breastfeeding has been an important topic in demographic research. It is demonstrated that breastfeeding has important consequences on post-partum amenorrhoea and birth interval on one hand and mortality and morbidity on the other. The traditional Indian society observes socio-culturally traditional patterns of prolonged breastfeeding in which breastfeeding is seen not only as a way of delaying the next birth but also as a cheap source of nutrition for the survival of the child. In rural areas of India, women continue to breastfeed their children exclusively for 8 months and in some cases for 12 months. The NFHS reports provide the estimates of median duration of breastfeeding based on current status method. Since, retrospectively reported data are not used by this method, reporting bias from mothers recall is not properly tackled in these estimates. The most popular non parametric methods by Kaplan and Meier (1958) and Nelson-Aelen (1978) for estimating survivorship functions which efficiently integrates the current status and retrospective data to estimate the survival probabilities has been applied here.

CONCLUSION

A comparison of the values shows that the current status method always tends to provide an overestimates of the survival probabilities and of the median duration as well. The results are otherwise consistent in that the longer duration of breastfeeding from the recent survey is evident.

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