ASIAN JOURNAL OF STATISTICS AND APPLICATIONS

VOL NO. 1, ISSUE 2, PAGE NO. 57-70, YEAR 2024

Smoothing Census Age Returns Using Interpolation

Jayanta Datta[a], Prasenjit Sinha[b]

[a,b] *Department of Statistics, Tripura University, Suryamaninagar, Agartala, INDIA*

ARTICLE HISTORY

Online Published December 27, 2024

ABSTRACT

The paper examines the adjustment of self-reported age data in Indian censuses. In this study, we attempted to smooth out the approximation of end digits in age reporting by adjustment of single-year age returns in Indian census data for 1991, 2001 and 2011. The primary objective of this study is to provide a reliable base population unaffected by digit preferences or avoidances. The proposed adjustment is based on the interpolation of equidistance arguments. Interpolation of equidistance arguments was applied for obtaining adjusted single-year age returns from the reported data by age and sex for the 1991, 2001, and 2011 Indian censuses. Adjusted data was re-evaluated for the presence of age errors. Myers Index, Whipple's Index, and Total Modified Whipple's Index were used to compare heaping in reported age data and adjusted age data. The re-evaluation of adjusted data shows that the quality of adjusted data was far better than the original self-reported data. Therefore, it is recommended that the adjusted data, being almost unaffected by digit preferences or avoidances, may be used as a base population for estimation of various demographic parameters.

KEYWORDS

Adjustment of single-year age returns, India, Census, Myers Index, Whipple's Index, Total Modified Whipple's Index

1. Introduction

Age is a fundamental and primary variable in a census or survey, but there has been erroneous reporting of age in census or survey data. Age approximations are often attributed to illiteracy, record-keeping, and deliberate misstatement of age [5]. The phenomenon of rounding off or approximating age by an informant is termed as 'heaping'. This approximation is not random in general and follows a systematic pattern ending with '0', '5' or even numbers and some other patterns.

In the Indian context, a significant proportion of the population in the country is still illiterate. Therefore, the age data from the census suffer from several problems, such as ignorance of age, negligence in reckoning the correct age, deliberate misstatement, and misunderstanding of the question [3]. Although illiteracy, inability, and ignorance lead to age approximation, the fundamental causes of errors in Indian census data are normative and behavioural [6].

The study of errors in age reporting requires special attention as the errors, partic-

CONTACT Author[a]. Email:statisticalofficer@tripurauniv.ac.in

ularly for census age distribution, are investigated more intensively than other information [7]. In evaluating data, it becomes necessary to investigate the magnitude and direction of the errors to make the required adjustment. Further, it is crucial to know the causes of the shortcomings in the data quality. Error detection in age reporting can be achieved using algebraic and graphical analysis. In the studies conducted by Jaffe (1951) [2], Shryock and Siegel (1976) [7], Ramachandran (1989) [5], Siegel, Swanson and Shryock (2003) [8], and Yusuf, Swanson and Martins (2014) [9], these methods have been explained in detail.

Various demographic parameters, viz. fertility, mortality, migration, and socio-economic characteristics like marriage, education, occupation, etc., required for planning, executing, and monitoring development plans are based on age data. The quality of these estimates depends on the quality of the base population. The importance of the variable age is quoted as "it is advisable to adjust the age data before its use in many fields of research" [4]. Therefore, it is desired to get correct data after rectifying defects from data by the adjustment method. The leading objective of this study is to obtain adjusted population by single-year age returns in Indian censuses for the years 1991, 2001, and 2011 and to re-evaluate the adjusted data for the presence of age errors.

2. Dataset

The data for this study is secondary, obtained from the RGI Government of India for the censuses 1991, 2001, and 2011 [1].

3. Methodology

A number of techniques are available for smoothing demographic data. These techniques are based on the assumption that the crest and trough in the observed data are due to errors. Moving averages, fitting mathematical models, curve fitting methods, interpolation methods, spline methods of interpolation etc., are a few to name.

Before smoothing out the irregularities, i.e., consecutive crest and trough patterns in the age data of a country or region, it is crucial to validate the chronology of the concerned country or region. Migration or a large-scale catastrophe, like famines, warfare, epidemics, etc., will have an evident impact on the region's or country's demography. Therefore, the factual consequences of age data reporting should never be smoothed.

The method of smoothing used here is the Interpolation method, a widely used methodology that is simple to understand and compute. This technique uses a set of constant multipliers to the quinquennial age data and obtains a distribution for single-year age returns. The formulae were initially derived in the year 1880 by famous actuary Thomas Bond Sprague and later transformed into a set of multipliers in the year 1921 by J.W. Glover[2].

These multipliers, called Sprague's multipliers, redistribute the aggregate within a quinquennial age interval into single years of age returns. The cumulative sum of the redistributed single-year age returns within the quinquennial age group, and the total count of the original quinquennial age group remains the same. Consider a quinquennial age distribution with age intervals 0-4 years, 5-9 years,..., 65-69 years, and above 70 years.

Here the last age interval is open ended and hence Sprague's multipliers cannot

be used to redistribute aggregate into single-year age returns. For all the other quinquennial age intervals Sprague's multipliers defined in tables 1 to 5 can be used to redistribute aggregate into single-year age returns. In this study, ages 0-69 years are considered due to the linear decrement in population that holds good for this age range.

Table 1. Sprague's multipliers for the 1st quinquennial age interval 0-4 years.

	Population in quinquennial age intervals			
	N_0	N_1	N_2	N_3
n_0	0.3616	-0.2768	0.1488	-0.0336
n_1	0.264	-0.096	0.04	-0.008
n_2	0.184	0.04	-0.032	0.008
n_3	0.12	0.136	-0.072	0.016
n_4	0.0704	0.1968	-0.0848	0.0176

Source: Census & Jaffe (1951)

Table 2. Sprague's multipliers for the 2nd quinquennial age interval 5-9 years.

	Population in quinquennial age intervals			
	N_0	N_1	N_2	N_3
n_0	0.0336	0.2272	-0.0752	0.0144
n_1	0.008	0.232	-0.048	0.008
n_2	-0.008	0.216	-0.008	0
n_3	-0.016	0.184	0.04	-0.008
n_4	-0.0176	0.1408	0.0912	-0.0144

Source: Census & Jaffe (1951)

Table 3. Sprague's multipliers for quinquennial age intervals 10-14 years, 15-19 years, ... up to 3rd last quinquennial age interval

	Population in quinquennial age intervals				
	N_{-2}	N_{-1}	N_0	N_1	N_2
n_0	-0.0128	0.0848	0.1504	-0.024	0.0016
n_1	-0.0016	0.0144	0.2224	-0.0416	0.0064
n_2	0.0064	-0.0336	0.2544	-0.0336	0.0064
n_3	0.0064	-0.0416	0.2224	0.0144	-0.0016
n_4	0.0016	-0.024	0.1504	0.0848	-0.0128

Source: Census & Jaffe (1951)

Table 4. Sprague's multipliers for the 2nd last quinquennial age interval

	Population in quinquennial age intervals			
	N_{-2}	N_{-1}	N_0	N_1
n_0	-0.0144	0.0912	0.1408	-0.0176
n_1	-0.008	0.04	0.184	-0.016
n_2	0	-0.008	0.216	-0.008
n_3	0.008	-0.048	0.232	0.008
n_4	0.0144	-0.0752	0.2272	0.0336

Source: Census & Jaffe (1951)

Table 5. Sprague's multipliers for the last quinquennial age interval

	Population in quinquennial age intervals			
	N_{-2}	N_{-1}	N_0	N_1
n_0	0.0176	-0.0848	0.1968	0.0704
n_1	0.016	-0.072	0.136	0.12
n_2	0.008	-0.032	0.04	0.184
n_3	-0.008	0.04	-0.096	0.264
n_4	-0.0336	0.1488	-0.2768	0.3616

Source: Census & Jaffe (1951)

Here, N_0 is the population of the quinquennial age interval to be converted into single-year age returns. N_{-1} and N_{-2} are preceding, and N_1 and N_2 are succeeding populations of quinquennial age intervals. Sprague's multipliers procedure involves multiplying each relevant table column with the appropriate value of N. The values of n_0 to n_4 are obtained as the row sum from each multipliers table (Table 1 to 5).

3. Result and Discussion

Figures 1 through 3 shows that the heaping of digits in the reported data has been smoothed out by applying Sprague's interpolation.

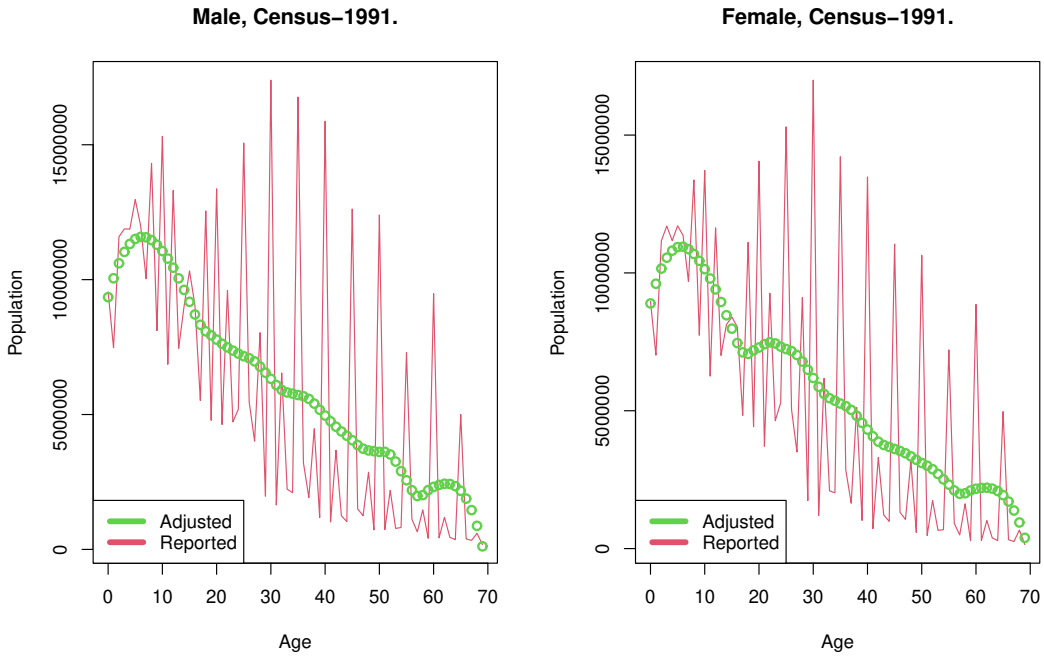

Figure 1. Reported and adjusted population for male and female, Census 1991

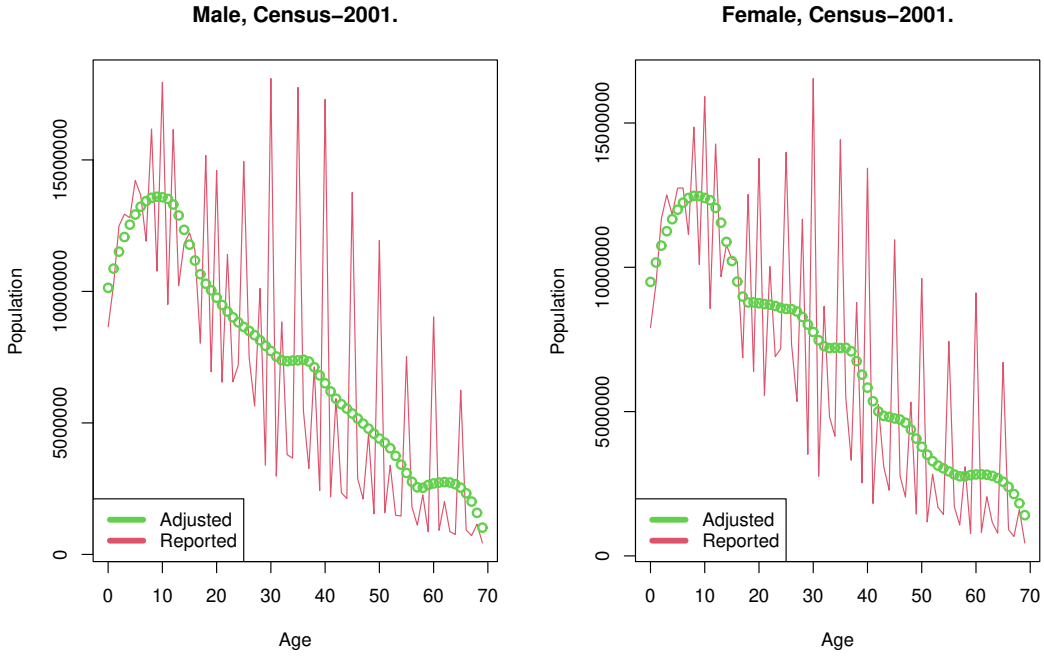

Figure 2. Reported and adjusted population for male and female, Census 2001

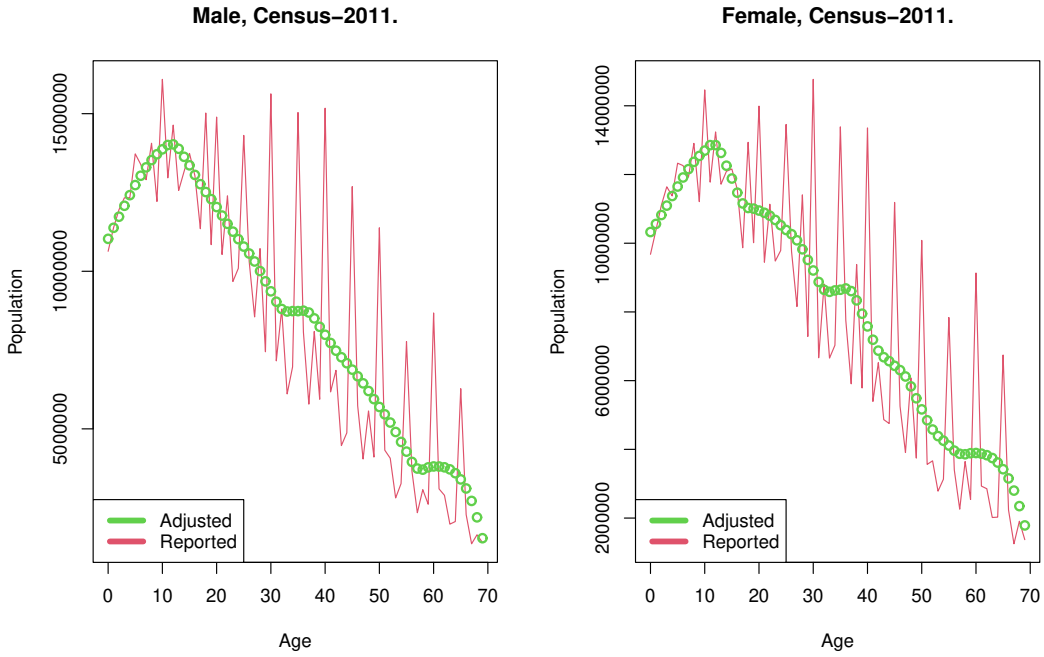

Figure 3. Reported and adjusted population for male and female, Census 2011

Adjusted population obtained using Sprague's interpolation formula for the age range 0-69 years are shown in Tables 6, 7, and 8.

Table 6.: Reported and Adjusted Population, Census-1991.

Begin of Table (T=Total; M=Male; F=Female)						
Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
0	18508485	18243295	9544406	9350830	8964079	8892465
1	14487535	19658903	7471790	10051029	7015745	9607874
2	22755790	20763486	11590190	10606651	11165681	10156835
3	23579984	21580190	11881844	11027752	11698140	10552437
4	23046238	22131219	11872503	11324389	11173735	10807769
5	24676682	22442357	12986350	11506168	11708332	10935909
6	23357126	22534470	11993511	11584494	11363975	10949977
7	19723238	22431103	10033918	11568073	9689230	10863030
8	27686556	22155799	14312222	11467412	13374334	10688166
9	15851130	21731043	8111523	11292567	7739607	10438476
10	29027602	21192934	15311047	11058329	13716555	10134605
11	13118793	20576690	6861510	10779490	6257283	9797199
12	24939761	19843987	13305117	10442428	11634644	9401559
13	14462244	18993383	7454575	10047729	7007669	8945655
14	17143498	18084904	9015381	9619654	8128117	8465250
15	18724354	17154792	10325432	9176680	8398922	7978111
16	17097611	16165527	9055588	8708873	8042023	7456654
17	10353352	15443573	5519173	8326248	4834179	7117325
18	23656856	15145696	12546779	8083582	11110077	7062113
19	9202756	15125342	4784102	7935691	4418654	7189651
20	27415889	15071305	13365429	7777155	14050460	7294150
21	8343814	15036361	4630254	7622510	3713560	7413851
22	18857638	14969260	9595545	7487827	9262093	7481433
23	9366403	14810103	4727963	7368418	4638440	7441685
24	10488960	14585675	5195032	7258313	5293928	7327362
25	30360199	14399353	15061479	7162522	15298720	7236831
26	10513030	14250488	5467392	7087590	5045638	7162898
27	7512909	13990970	4011539	6969589	3501370	7021381
28	17139018	13563756	8033850	6779571	9105168	6784186
29	3714102	13034690	1972327	6547315	1741775	6487375
30	34390085	12512790	17396266	6324149	16993819	6188641
31	2852247	11959614	1647397	6090924	1204850	5868690
32	12712070	11520046	6539557	5910637	6172513	5609409
33	4326914	11271883	2233521	5816956	2093393	5454927
34	4123168	11140152	2101024	5775100	2022144	5365052
35	30981180	10983690	16768198	5721712	14212982	5261978
36	6062347	10844663	3211834	5675579	2850513	5169084
37	3567659	10612376	1923169	5580503	1644490	5031874
38	9583662	10222011	4472854	5404086	5110808	4817925
39	2204022	9736130	1182245	5176420	1021777	4559710
40	29354909	9278891	15874081	4961608	13480828	4317282
41	1742872	8821587	1017752	4748768	725120	4072819
42	6977953	8424551	3673865	4547900	3304088	3876651

Continuation of Table 6

Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
43	2464677	8129070	1247304	4371062	1217373	3758009
44	2015928	7902240	1029243	4212907	986685	3689333
45	23663282	7660225	12619050	4046832	11044232	3613393
46	2815273	7408228	1499847	3867113	1315426	3541115
47	2307133	7189905	1250321	3732937	1056812	3456968
48	6038008	7014845	2862148	3667554	3175860	3347292
49	1310102	6860594	723195	3640126	586907	3220468
50	23036231	6719967	12396632	3613911	10639599	3106056
51	1209534	6624237	733501	3617075	476033	3007162
52	3933147	6397680	2186678	3518485	1746469	2879195
53	1440800	5961663	777379	3255838	663421	2705825
54	1493880	5410045	810700	2899581	683180	2510463
55	14506385	4879982	7298270	2561171	7208115	2318811
56	2029850	4301643	1116032	2192766	913818	2108877
57	1145375	3966373	650402	1978361	494973	1988012
58	3090835	4019427	1465209	2012585	1625626	2006842
59	700057	4305077	411834	2196864	288223	2108213
60	18335174	4487003	9478824	2316708	8856350	2170295
61	721564	4590067	429296	2389464	292268	2200603
62	2207592	4639131	1190060	2432480	1017532	2206651
63	833054	4598859	446290	2424463	386764	2174396
64	651592	4433916	362767	2344121	288825	2089795
65	9966467	4108968	4998209	2170162	4968258	1938806
66	711910	3588678	388753	1881292	323157	1707386
67	590798	2837712	334629	1456221	256169	1381491
68	1266046	1820733	593906	873654	672140	947079
69	323278	502408	178133	112301	145145	390107

End of Table

Table 7.: Reported and Adjusted Population, Census-2001.

Begin of Table (T=Total; M=Male; F=Female)						
Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
0	16561349	19629566	8648208	10136038	7913141	9493527
1	19647573	21031787	10246425	10866829	9401148	10164958
2	24168984	22261577	12486394	11510670	11682590	10750908
3	25443946	23319224	12937405	12067763	12506541	11251460
4	24625312	24205011	12801180	12538312	11824132	11666699
5	26959509	24919224	14216386	12922517	12743123	11996708
6	26412941	25462151	13663205	13220580	12749736	12241571
7	23045028	25834074	11910330	13432704	11134698	12401370
8	31031074	26035282	16174274	13559091	14856800	12476191
9	20868238	26066059	10770638	13599942	10097600	12466117
10	33855378	25982949	17941703	13578722	15913675	12404227
11	18078949	25842497	9505257	13518894	8573692	12323603
12	30427429	25363695	16153819	13304351	14273610	12059344
13	19897051	24434311	10219364	12888770	9677687	11545540
14	22588051	23223407	11812734	12342141	10775317	10881266
15	22521059	21996165	12225932	11778821	10295127	10217344
16	21777810	20680217	11572289	11173600	10205521	9506617
17	14898862	19639124	8033721	10653750	6865141	8985374
18	27686902	19074740	15166111	10293562	12520791	8781178
19	13331257	18825644	6941938	10040258	6389319	8785386
20	28367204	18517494	14595850	9763109	13771354	8754385
21	12110022	18211879	6548123	9483869	5561899	8728010
22	21428918	17940123	11404995	9234550	10023923	8705573
23	13465533	17676026	6562775	9016620	6902758	8659406
24	14392455	17418610	7209407	8823001	7183048	8595609
25	28917266	17206304	14934412	8648833	13982854	8557472
26	14816846	17047272	7474319	8499511	7342527	8547761
27	10990931	16804030	5640459	8336352	5350472	8467677
28	21781213	16416962	10112839	8141004	11668374	8275958
29	6916137	15947825	3395517	7931846	3520620	8015979
30	34634209	15491457	18093460	7733278	16540749	7758180
31	5739449	14997050	2977527	7525618	2761922	7471433
32	17482474	14652251	8837855	7385316	8644619	7266935
33	8610078	14549752	3791820	7348103	4818258	7201649
34	7807834	14583534	3661254	7369601	4146580	7213932
35	32175754	14583110	17754473	7379278	14421281	7203832
36	10948347	14616451	5459654	7402732	5488693	7213719
37	6584873	14422953	3268803	7334090	3316070	7088864
38	15905963	13866557	7126262	7117190	8779701	6749366
39	4959148	13085014	2429535	6805437	2529613	6279577
40	30733879	12337739	17299610	6506544	13434269	5831196
41	4002930	11555573	2184688	6196751	1818242	5358822
42	11168253	10925106	5922453	5920849	5245800	5004257
43	5432438	10559818	2346733	5711266	3085705	4848552
44	4400797	10360061	2125231	5543305	2275566	4816756
45	24710862	10119713	13759010	5357844	10951852	4761870

Continuation of Table 7

Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
46	5659548	9888408	2885114	5164314	2774434	4724094
47	4146735	9587350	2110068	4973031	2036667	4614320
48	9899369	9159333	4570723	4782441	5328646	4376891
49	2992462	8654172	1542971	4590257	1449491	4063915
50	21540415	8189946	11929738	4407777	9610677	3782170
51	2757432	7756309	1582201	4247188	1175231	3509121
52	6225881	7318613	3389644	4036475	2836237	3282138
53	3164651	6875766	1487972	3745575	1676679	3130191
54	2899180	6446924	1462053	3414594	1437127	3032330
55	14963273	6026142	7531157	3097077	7432116	2929065
56	3518257	5583177	1809330	2762368	1708927	2820809
57	2177975	5311288	1110799	2551781	1067176	2759506
58	5355016	5296030	2267315	2534680	3087701	2761350
59	1638826	5436710	864421	2637116	774405	2799594
60	18141973	5520884	9029205	2699157	9112768	2821727
61	1733310	5559609	918063	2732842	815247	2826767
62	4064010	5563942	2013153	2750210	2050857	2813732
63	2032394	5507688	866527	2734637	1165867	2773051
64	1545092	5364655	759399	2669501	785693	2695154
65	12943767	5108649	6240628	2538177	6703139	2570472
66	1842746	4713477	931608	2324044	911138	2389433
67	1389037	4152944	716620	2010477	672417	2142467
68	2751020	3400859	1149161	1580854	1601859	1820005
69	880385	2431027	434086	1018551	446299	1412475

End of Table

Table 8.: Reported and Adjusted Population, Census-2011.

Begin of Table (T=Total; M=Male; F=Female)						
Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
0	20311234	21354668	10633298	11029103	9677936	10325565
1	21755197	21940046	11381468	11378917	10373729	10561129
2	23056268	22551089	11952853	11730777	11103415	10820312
3	23974041	23172398	12331431	12078274	11642610	11094124
4	23710038	23788577	12333024	12415003	11377014	11373574
5	26054230	24384226	13725480	12734554	12328750	11649672
6	25654245	24943949	13394700	13030520	12259545	11913429
7	24826640	25452347	12903364	13296493	11923276	12155854
8	26968373	25894024	14061937	13526067	12906436	12367957
9	23424638	26253580	12214985	13712832	11209653	12540748
10	30552107	26564688	16089436	13868940	14462671	12695748
11	24740946	26861018	12962604	14006539	11778342	12854479
12	27877307	26881828	14637892	14026435	13239415	12855393
13	24280683	26513584	12563775	13885106	11716908	12628478
14	25258169	25888094	13165128	13631816	12093041	12256278
15	25899454	25244320	13739746	13361142	12159708	11883178
16	24592293	24526812	13027935	13056315	11564358	11470497
17	21217467	23920435	11349449	12762729	9868018	11157706
18	27958147	23538965	15020851	12513253	12937296	11025712
19	20859088	23295917	10844415	12288957	10014673	11006960
20	28882735	22987985	14892165	12037080	13990570	10950905
21	19978972	22652180	10532278	11767021	9446694	10885158
22	23528225	22305471	12392976	11504681	11135249	10800790
23	19154055	21934795	9674189	11257348	9479866	10677447
24	19880235	21543792	10093085	11018563	9787150	10525229
25	27768078	21168642	14311524	10783191	13456554	10385451
26	20076997	20825483	10315030	10562600	9761967	10262883
27	16709350	20395338	8552032	10310694	8157318	10084645
28	22127016	19830130	10719926	10007359	11407090	9822771
29	14732524	19194372	7445696	9680365	7286828	9514007
30	30399029	18570879	15628996	9363878	14770033	9207002
31	13823245	17907351	7157502	9034599	6665743	8872752
32	17613544	17447038	8801105	8803251	8812439	8643787
33	12764541	17307936	6108879	8723123	6655662	8584813
34	13994592	17361746	6964192	8735822	7030400	8625924
35	28422631	17381107	15036666	8735426	13385965	8645681
36	15827717	17434205	8067568	8750029	7760149	8684176
37	11692231	17296966	5784879	8690854	5907352	8606112
38	17471758	16842187	8090401	8505222	9381357	8336965
39	11726347	16186220	5939867	8237850	5786480	7948369
40	28528992	15563478	15173411	7984767	13355581	7578710
41	11567894	14916111	6172297	7725127	5395597	7190984
42	13380642	14354684	6856826	7480840	6523816	6873844
43	9334352	13954264	4468914	7271916	4865438	6682349
44	9626232	13649575	4873938	7082736	4752294	6566839
45	23872961	13310599	12685175	6878944	11187786	6431655

Continuation of Table 8

Ages	Reported(T)	Adjusted(T)	Reported(M)	Adjusted(M)	Reported(F)	Adjusted(F)
46	10992678	12975733	5735540	6668938	5257138	6306796
47	7951297	12566570	4043122	6445280	3908175	6121290
48	11649592	12035034	5568554	6201326	6081038	5833708
49	7851799	11430390	4105723	5943626	3746076	5486764
50	21462422	10858159	11379329	5694537	10083093	5163622
51	7885966	10307057	4323584	5460580	3562382	4846477
52	7735164	9778667	4068700	5200946	3666464	4577721
53	5590790	9287605	2808043	4901131	2782747	4386474
54	6394912	8837767	3263610	4586073	3131302	4251694
55	15607546	8389364	7769352	4278194	7838194	4111170
56	7071837	7915472	3666804	3952590	3405033	3962882
57	4599026	7612678	2339391	3741425	2259635	3871254
58	6718934	7563668	3072508	3706215	3646426	3857453
59	5148712	7664872	2607957	3777588	2540755	3887285
60	17810689	7700965	8677046	3807631	9133643	3893334
61	6026813	7680131	3095448	3805507	2931365	3874624
62	5745143	7610552	2892015	3780375	2853128	3830177
63	3994105	7463163	1977207	3715218	2016898	3747945
64	4086957	7208896	2060033	3593018	2026924	3615878
65	13022352	6818682	6275854	3396756	6746498	3421925
66	4511946	6263454	2278670	3109416	2233276	3154038
67	2605082	5514145	1353711	2713980	1251371	2800166
68	3548373	4541688	1640034	2193429	1908339	2348259
69	2767230	3317014	1396057	1530745	1371173	1786269

End of Table

Table 9. Age data quality indicators for the reported and adjusted data for the age range 0-69 years

Census	Quality Indicators	Reported			Adjusted		
		Total	**Male**	**Female**	**Total**	**Male**	**Female**
1991	Myers' Index	63.60	62.56	64.74	1.70	1.81	1.57
	Whipple's Index	290.30	292.56	287.88	100.05	100.06	100.04
	Total Modified WI	7.67	7.75	7.71	0.01	0.03	0.02
2001	Myers' Index	48.01	49.26	46.65	1.62	1.31	2.11
	Whipple's Index	229.99	241.03	218.42	100.00	99.99	100.00
	Total Modified WI	5.52	5.71	5.31	0.04	0.07	0.00
2011	Myers' Index	24.41	24.17	24.65	1.58	1.29	1.90
	Whipple's Index	171.04	174.55	167.00	100.02	100.00	100.05
	Total Modified WI	2.85	2.99	2.83	0.03	0.01	0.05

Re-evaluation of adjusted data

The re-evaluation of the adjusted data by various indicators of the age data quality, as shown in Table 9, clearly indicates that the measure of age data errors in the adjusted data is very low compared to the reported data.

5. Conclusion

In this study, we attempted to smooth out the biases in the age reporting in the Indian Census data for the years 1991, 2001, and 2011 using Sprague's interpolation for equidistant arguments. Adjusted populations were re-evaluated by using the Myers Index, Whipple's Index, and Total modified Whipple's Index. The re-evaluation of adjusted data shows that the quality of adjusted data was far better than the original self-reported data. Results obtained from various age data quality indicators show that the heaping in data has been smoothed out, and the data quality has been improved substantially for five-year age groups across the censuses. Therefore, it is recommended that the adjusted data, being almost unaffected by digit preferences or avoidances, may be used as a base population for the estimation of various demographic parameters. However, data adjustment should not substitute the care and caution required in collecting data. An efficient and effective data collection is always better than the best data adjustment models.

References

[1] Census of India Website: Office of the Registrar General & Census Commissioner, India. (n.d.). *Retrieved August 13*, (2021), from https://censusindia.gov.in/.

[2] Census, U. S. B. of the, A. J. Jaffe. *Handbook of Statistical Methods for Demographers: Selected Problems in the Analysis of Census Data*. U. S. Government Printing Office, (1951).

[3] P. A. Jaipal, P. Visaria. Influence of literacy and education on the quality of age returns. *Demography India*, 4(1), 11–15 (1975).

[4] D. KERR. An alternate strategy for evaluating and generating censal estimates. Genus, 59(3/4), 71–89 (2003).

[5] K. V. Ramachandran. Errors and Deficiencies in Basic Demographic Data: Overview of methods of Detection, Evaluation and Adjustment in Fertility and mortality Estimation in Africa. Proceedings of a Workshop on the Estimation of Fertility and Mortality in Africa, Held at RIPS, University of Ghana, (1989).

[6] P. C. Saxena, K. R. Verma and K. R. Sharma. Errors in age reporting in India: a socio-cultural and psychological explanation. *Indian Journal of Social Work*, 47(2), 127–135 (1986).

[7] H. S. Shryock, J. S. Siegel and E. G. Stockwell. The methods and materials of demography (Condensed ed). Academic Press, (1976).

[8] J. S. Siegel, D. A. Swanson and H. S. Shryock. The methods and materials of demography, (2003).

[9] F. Yusuf, D. A. Swanson and J. M. Martins. Methods of demographic analysis. Springer, (2014).