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Modelling and Forecasting Age-Specific Mortality Rates in India

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Abstract
Background: For several decades, global public-health efforts have focused on the development and application of various programs to improve child survival in developing countries. By contrast, little emphasis has been placed on adult and old age mortality especially in a developing country like India.
Aims & Objectives: To check the suitability of the Lee-Carter model in the Indian context, to measure the level and trend of mortality by age and sex in India during 1996-2015 and to forecast age-specific death rates for males and females in India up to 2041.
Material & Methods: The Lee-Carter model has been used for mortality forecasting in India. The model was applied to the age-specific death rate of India by sex for aged 0-85+ years.
Results: Finding reveals that the Lee-carter model very well fit for India. Furthermore, it is noted that recently, males have a higher mortality rate than females in India. The prediction shows that male population will experience a gradual decline in mortality by 2016-2041.
Conclusion: the Lee-carter model can be used in the situation of India for estimating forecasting mortality and the result shows that male populations lived to higher risk mortality situation. This is a first study to give forecast age-specific death rate for starting age group 0-1 and 1-5 and after five year up to 85+ years. This can be useful for generating direct life table by software without using any adjustment.

Keywords: Mortality forecasting; Adult Mortality; Public health; Lee-Carter methodology; Time series.

Introduction
Indicators derived from mortality rates provide a good picture of overall health of population. These indicators include infant and child mortality, adult mortality and overall life expectancy at birth. Kinggsley Devis spoke that the "Incredible decline" of mortality in developing countries [1]. No doubt, India has observed the same successes story [2]. Since independence, the public health program has focused largely on child and infant survival enhancement and hence this decline mostly credited to the child mortality. This has led to the rapid decline in the infant mortality rate (IMR). According to Sample Registration System (SRS), IMR dropped from 129 to 36 per thousand live births during 1971 to 2017 in India. On the other hand, the share of adult (15-59 years) mortality among males increased from 31% to 34% and female increased from 26.5% to 27.5% in India during 2001 to 2010. Adult mortality rate increased from 269 deaths in 1970 to 310 death per 1000 population in 2014 with growing at an average annual rate of 1.72%. Thus, slowing the pace of the decline of infant and child mortality rate calls for the policy shift from the maternal-child health to the life style related among the adults.
For several decades, public health efforts worldwide have focused on developing and implementing disease control programs to improve children survival in India. On the contrary, there has been little emphasis on the mortality of adults in India. Although there have been least attempts to measure adult mortality. As a result, many are greatly ignorant of current level and patterns of adult mortality in India and how they are changing over time.
However, there are very few systematic attempts have been made on the trends and patterns of adult mortality in India [3].

The proposed method Lee and Carter (1992) becomes the "most leading statistical model for predicting mortality in demographic literature" [4]. Recently, the this model has become increasingly popular and applied for the long-term prediction of mortality rates for a specific age in many countries and time periods. For example, the United Nation [5], Canda [6], Japan [7], seven economically more developed nations (G7) [8].

Aims & Objectives

1. To check the suitability of the Lee-Carte model in the Indian context for recent time periods.
2. To measure the level and trends of mortality by age and sex in India during 1996-2015.
3. To forecast age-specific death rates (ASDR) for males and females for periods 2016-2041.

Material and Methods

Data

In India, the SRS is the only source that provides the mortality estimates. In this study, the SRS data used to understand the mortality by age and sex in India. Data is taken for all the years 1996-2015 for males and females separately. The studies used shorten the length of historical data to avoid outliers and discrepancy of the data [9-10].

Methodology

The Lee-Carter model

Let $m(x,t)$ denote the death rate for age x in the year t. The original Lee-carter model goes on to forecast $m(x,t)$for given t, using the model

$$\ln m(x,t) = a_x + b_x * k_t + \varepsilon_{x,t} \quad (1)$$

where a_x, coefficient describe the expected shape of mortality by age, b_x, coefficient describe the rate of mortality change or which rates mortality decline in response to change in k_t. k_t, is the index of level of mortality and $\varepsilon_{x,t}$, is the residual at age x and time t.

The parameter estimation using singular value decomposition (SVD) technique. For more details and as well as different way of estimating technique in given in Lee-Carter (1992).

For forecasting of k_t values the Autoregressive Integrated Moving Average Model (ARIMA) (0,1,0) has been used. After getting the forecasted values of k_t the ASDR can be forecasted by using the estimated value a_x, b_x and the forecasted value of k_t using the above equation[11].

Results

After applying the Lee-Carter method for parameter estimation for both male and female mortality data, we arrived at the following results.

Fig.1 shows that the expected mortality of log of age specific mortality from the figure we see that ax values, starting for the lowest age group, the level of mortality is continue to decline up to age 15-19 and then increased mortality as age is increased. From figure1 it is clear that the mortality differential is exist and it is continue increase with age and it is clear that males is higher risk at age increase as comparison to females.

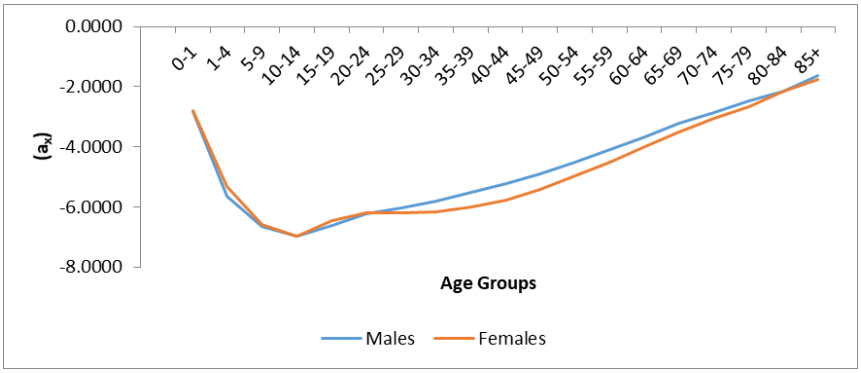

Fig. 1: General Pattern of Mortality (a_x) by Age in India, 1997-2014

Fig.2 shows that the relative pace of change or seed in decline in the mortality by age and it is clear show that females in the higher risk in the age group 0-1 to 10-14 year and the mortality decline in the male is higher in the age groups 15-19 to 44-49 year it may be due to advancement in the maternal health facility.

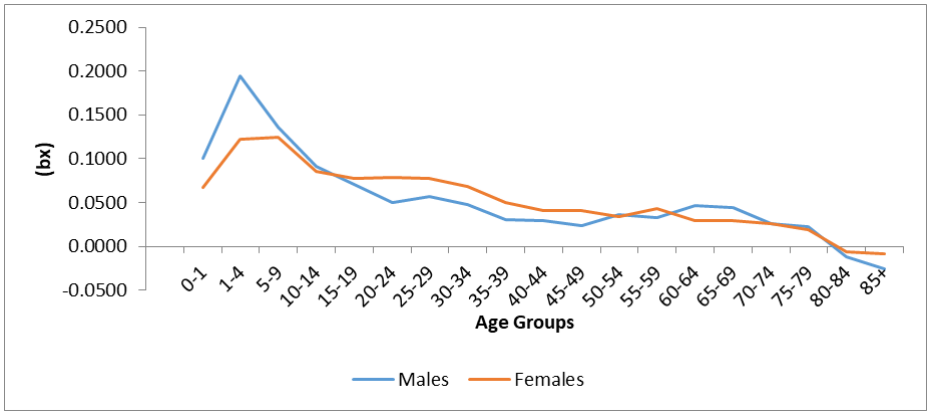

Fig. 2: Relative Pace of Change in Mortality (b_x) by Age in India, 1997-2014

After estimating the parametersa_x, b_x and k_t, we have estimated the ASDR for three selected period namely 2001, 2006 and 2011 by males and females. The main idea is examine the difference is observed and expected ASDR. From **Table1** it can be seen that there is not much difference in the expected and observed values. It indicates the suitability of Lee-Carter model in Indian context by male as well as females.

To forecasting mortality, we need forecast value of k_t, in this study we also use ARIMA (0,1,0) suggested by Lee and Cater [8] to forecast the index of level of mortality k_t.

Table. 1: Observed and Expected ASDR for India

Age Group	Male						Female					
	2001		2006		2011		2001		2006		2011	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
0-1	69.1	69.0	58.7	61.0	45.6	48.9	71.4	76.7	61.1	60.1	47.8	43.9
1-4	4.6	4.9	3.9	3.8	2.4	2.5	6.5	6.0	5.4	3.7	3.7	2.0
5-9	1.6	1.6	1.4	1.3	1.0	1.0	1.9	1.8	1.5	1.3	1.0	0.9
10-14	1.2	1.1	1.0	1.0	0.8	0.8	1.2	1.2	1.0	0.9	0.7	0.7
15-19	1.5	1.5	1.4	1.4	1.2	1.2	1.9	1.6	1.7	1.4	1.3	1.1
20-24	2.1	2.1	2.0	2.0	1.8	1.8	2.6	2.2	2.1	2.0	1.7	1.7
25-29	2.8	2.6	2.4	2.4	2.2	2.2	2.7	2.8	2.0	2.4	1.6	2.0
30-34	3.3	3.3	3.1	3.1	2.8	2.8	2.5	3.4	2.1	3.0	1.7	2.6
35-39	4.4	4.3	4.1	4.1	3.9	3.8	3.1	4.4	2.5	4.1	2.0	3.7
40-44	5.4	5.6	5.4	5.4	5.2	5.0	3.4	5.7	3.0	5.3	2.6	4.9
45-49	8.0	7.8	7.5	7.6	7.3	7.2	5.0	8.0	4.2	7.6	4.0	7.0
50-54	11.8	11.8	10.7	11.3	10.2	10.4	7.5	12.3	6.1	11.2	6.0	10.0
55-59	18.6	17.6	15.3	16.9	16.4	15.7	12.9	18.2	10.6	16.8	9.6	15.1
60-64	26.2	27.5	24.9	25.9	24.3	23.4	18.9	28.8	18.5	25.8	16.8	22.3
65-69	44.0	42.5	37.9	40.2	39.2	36.5	33.1	44.6	28.3	40.0	28.4	34.8
70-74	56.4	60.4	58.8	58.4	56.4	55.2	46.1	62.0	49.0	58.2	43.6	53.7
75-79	88.0	87.9	84.3	85.5	79.1	81.4	74.2	89.9	65.4	85.2	64.8	79.5
80-84	107.5	114.8	118.4	116.5	109.2	119.6	92.8	113.3	201.1	116.7	96.2	121.1
85+	178.9	185.2	186.8	191.2	182.8	202.3	157.1	180.3	183.1	191.9	156.6	207.9

Fig3. Shows that the estimate mortality index for the period 1997-2014 with forecasted values of k_t with 95 % confidence interval (CI) for the year 2015 to 2041. From the figure we found that the CI in female is much wider as comparison to male. That show that female is the advantage situation due to improvement in the health condition on the other hand male have much higher mortality condition may be due to life style, workplace etc.

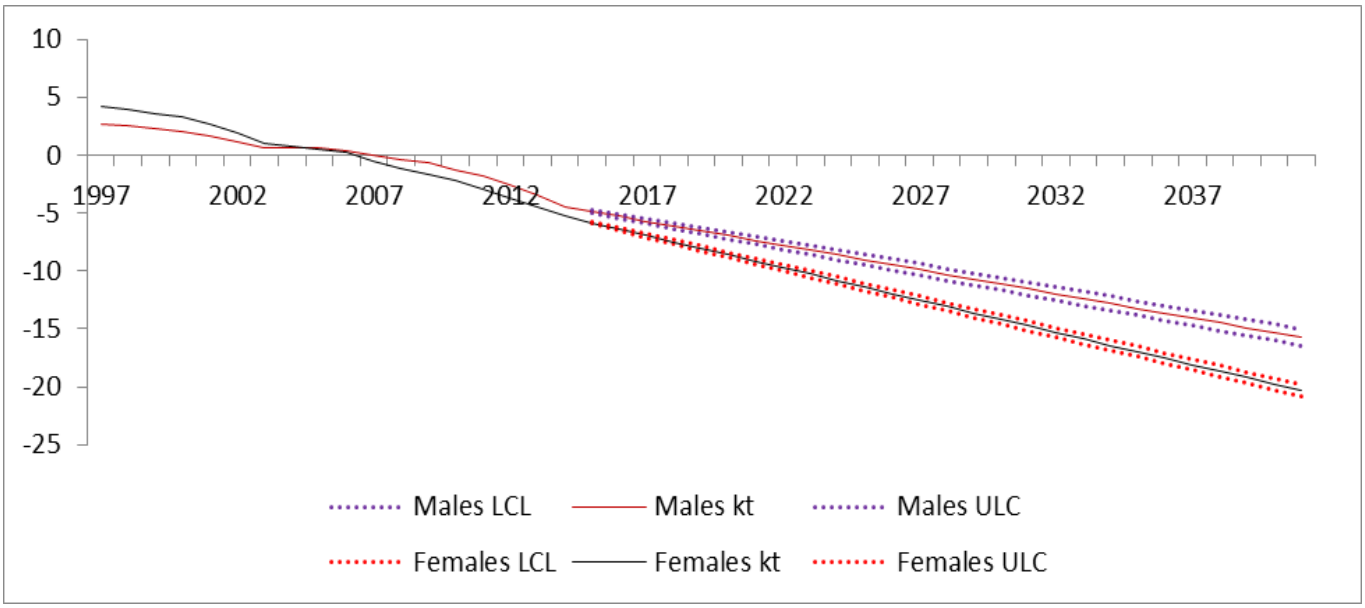

Fig. 3: Estimates and Forecasts of Mortality Index (K_t), with 95% Confidence Interval, from ARIMA (0, 1, 0) model for Males and Females in India, 1997-2041

Table 2 provides the forecast ASDR for the year 2016 to 2041 with 5 year interval for male and female respectively. The mortality rate in India expected to decline rapidly under age one is expected to decline from 35 to 12 per thousand in males and from 31 to 8 per thousand in female for the year 2016 to 2041. Overall the death rate for the age group 5-9 to 25-29 year are expected to go below one per thousand between the forecast years 2016 to 2041 for both the sexes. Table 2 is also useful for generating life-table. This forecast ASDR data use as a input ASDR for generating future life-table by using pre-define software as example MortPak[12].

Table. 2: Forecast ASDR for males and females in India by selected years

Age Group	2016		2021		2026		2031		2036		2041	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0-1	34.63	31.02	28.09	23.46	22.79	17.74	18.48	13.42	14.99	10.15	12.16	7.68
1-4	1.28	1.03	0.85	0.60	0.57	0.35	0.38	0.20	0.25	0.12	0.17	0.07
5-9	0.63	0.54	0.47	0.37	0.35	0.25	0.27	0.17	0.20	0.12	0.15	0.08
10-14	0.57	0.51	0.47	0.40	0.39	0.31	0.32	0.24	0.26	0.18	0.22	0.14
15-19	0.93	0.86	0.80	0.70	0.69	0.58	0.59	0.47	0.51	0.39	0.44	0.32
20-24	1.50	1.42	1.35	1.23	1.21	1.07	1.09	0.93	0.98	0.81	0.89	0.70
25-29	1.77	1.66	1.57	1.41	1.39	1.20	1.23	1.03	1.09	0.87	0.97	0.75
30-34	2.35	2.23	2.13	1.96	1.93	1.71	1.75	1.50	1.58	1.32	1.43	1.15
35-39	3.46	3.34	3.24	3.07	3.04	2.82	2.85	2.59	2.68	2.38	2.51	2.18
40-44	4.56	4.41	4.29	4.07	4.04	3.76	3.80	3.47	3.58	3.20	3.37	2.95
45-49	6.65	6.48	6.34	6.07	6.03	5.69	5.74	5.33	5.47	4.99	5.21	4.68
50-54	9.21	8.85	8.54	8.00	7.92	7.23	7.34	6.54	6.81	5.92	6.31	5.35
55-59	13.97	13.47	13.04	12.28	12.16	11.20	11.35	10.21	10.59	9.30	9.88	8.48
60-64	19.99	19.00	18.15	16.70	16.48	14.69	14.97	12.91	13.59	11.35	12.34	9.98
65-69	31.29	29.80	28.51	26.32	25.98	23.25	23.67	20.53	21.57	18.14	19.66	16.02
70-74	50.49	49.07	47.83	45.64	45.30	42.46	42.91	39.50	40.65	36.74	38.50	34.18
75-79	75.41	73.59	72.00	69.17	68.73	65.02	65.61	61.12	62.64	57.45	59.80	54.00
80-84	124.59	126.24	127.74	130.52	130.97	134.93	134.28	139.50	137.67	144.22	141.15	149.11
85+	220.99	227.32	233.15	244.16	245.98	262.26	259.52	281.70	273.81	302.58	288.88	325.00

Conclusion

The goodness of fit shows that the Lee-Carter model follows the mortality pattern very well for most of the ages for the males and females. The model was able to fit the mortality rates despite the fluctuation mortality pattern. The results of forecasted k_t show a gradual decline in mortality shown an upward trend from age 15-85+ years all things being equal. We conclude that the Lee-cater model can be used to model both the males and females mortality in India.

Recommendation (Public health importance)

On the basis of k_t values, we can forecast the future age pattern of mortality. This can be of immense help particularly for population projection, planning as well as generation of future life tables.

Limitation of the study

Since Lee-carter published this model for long-run forecast of the level and age pattern of mortality in 1992, there have been a number of extensions of the method, including the development of coherent forecast by sex and by race etc. but this paper is only an initial investigation into the attributes of an original lee-carter model used for estimation and forecasting mortality.

Authors Contribution

All authors have contributed equally.

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