Influenza in India 1918: epicenter of an epidemic

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Abstract

Routine demographic data from censuses and civil registration for India for the period 1901 to 1921 are used to assess the size and regional distribution of the impact of the 1918 influenza epidemic. Methods of data evaluation are used to adjust for possible under- (or over-) reporting of deaths relative to census counts; given the nature of the age groups used these methods are given some modification. The analysis presents estimates for the country, provinces (now called states) and finally focuses on the districts of Central Provinces and Berar, the area which appears to have been most severely affected of all the areas of India. Analysis of adjusted data suggests that previous estimates of "excess" deaths in the range of 17.5 to 22.5 million were probably too high, having not adequately taken into account the effect of the epidemic on births; our estimates are in the range of 11.0 to 13.5 million. Even so, the "excess" crude death rate between August 1918 and January 1919 is estimated to have averaged over 30 per 1,000, and in Central Provinces to have exceeded 60 per 1,000. For the districts of Central Provinces, associations between excess death rates and other characteristics are explored; severity is found to be positively associated with rainfall, and negatively associated with the sex ratio of the population and emigration rates, but a number of socio-economic indicators including initial mortality level showed no association with excess mortality.

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"For sanitary purposes it is indispensable to know the relative mortality in small and, as far as possible, well-defined tracts to ascertain the death rates in each of these communities; to see how far this arises from preventable causes; and to apply the remedies"

Sanitary Commissioner of the Government of India (1869)

Introduction

Influenza arrived in Bombay in early September 1918, and swept north and east across the country. Kingsley Davis (1951), using both adjusted registered deaths and a shortfall of intercensal population growth between 1911 and 1921 relative to the preceding and subsequent decades, estimated the impact at somewhere between 18.5 and 22.5 million excess deaths. Mills (1989), using the same basic data but different adjustment methods and different comparison periods, revised Davis's estimates down slightly to a range of 17.4 to 18.5 million. A more recent review of the global impact of the epidemic estimated that it raised the crude death rate in India in the years 1918 to 1920 by 14 per 1,000 population above the average for 1914-17 and 1921-24 (Murray et al., 2006), half as much again as the impact in the next most severely impacted country (Table 1). However, this impact was almost entirely concentrated in the months of September to December 1918, in which period the crude death rate rose in some provinces to over 100 per 1,000 person-years of exposure, and for India as a whole rose to a reported 16 per 1,000 population in November 1918. Figure 1 shows the ratio of deaths in each month from August 1918 to March 1919 relative to the average number of deaths in the corresponding months of the preceding and following years for India and for major provinces. In Bombay and Central Provinces, the impact in the peak month is to increase deaths by a factor of over 10, but other provinces were much less severely affected. In this paper we explore these differences with particular emphasis on Central Provinces.

Data

Data for this analysis come from the official population data available for India. At the time, approximately 75% of the population of the subcontinent lived in areas administered by the British, the remaining 25% living in "Princely" states. Information on population by age and sex (and province and district) are drawn from the 1901, 1911 and 1921 censuses of India, which covered both types of area. Information on annual deaths (by age and sex at the national and provincial level) and monthly deaths (down to the district level) come from the civil registration system, which only operated in areas administered by the British; these data are taken from annual Statistical Abstracts and annual reports of provincial sanitary commissioners, supplemented with data published in provincial census reports.

Reporting of deaths for India in this period is assumed to have been incomplete, even in areas where registration did occur, but in some provinces reporting seems to have been good, at least in terms of overall numbers. Deaths are available classified by cause, but the causes recorded do not closely correspond to current disease concepts and classifications, so we focus on temporal fluctuations in total deaths.

Methods

Given the data available, there are a number of ways in which the severity of the epidemic can be assessed. One way, not dependent on the registration of deaths, and therefore applicable to the whole of the sub-continent, is to compare population change between the 1911 and 1921 censuses to that between the 1901 and 1911 censuses; this is one approach followed by Davis (1951) and Mills (1989), but only at the aggregate level. It can then be argued that if the only major difference in terms of components of population change between the two decades was the influenza epidemic, any shortfall in growth between 1911 and 1921 was the result of the epidemic. Here we assess population shortfall at all ages and at ages 5 and over: changes in the population under 5 (in 1921) may be affected by changes in births as well as deaths related to the epidemic. We use growth rates of the total population and of the population 5 and over between 1901 and 1911 to estimate what the population of all ages and aged 5 and over would have been in 1921 given stable growth; the difference between the estimated population and the recorded one is the estimate of the net demographic effect of the epidemic, which for the population aged 5 and over can be regarded as exclusively the result of excess deaths.

An alternative approach is to use information on registered deaths. Since death registration was only implemented in the areas administered by the British, and even in those areas was regarded as incomplete, strictly speaking results can only apply to such areas. However, if it can be assumed that age patterns of population and deaths were similar in British India and the states, the broad magnitude and time pattern of the excess mortality from the epidemic can be examined as the ratio of deaths in each month from August 1918 to July 1919 to the average number of deaths for the same months for the preceding and following years; these ratios will be unaffected by any constant level of under-registration of deaths. Further, techniques for evaluating the completeness of death registration relative to census enumeration are be applied using the registered deaths for British-administered India and census counts for the whole sub-continent. Mills (1989) uses one such approach (the Brass (1975) Growth Balance method) to arrive at his estimate of 17.4 million excess deaths.

A number of more flexible methods have been developed for assessing the completeness of death registration relative to population counts (for example Bennett and Horiuchi 1981, Hill 1987). The Brass methodology assumes a stable population, probably a close approximation to the case on India in the 1910s except for the effects of the influenza epidemic, whereas the other two methods assume only a closed population. All the methods, however, require information on population and deaths by age groups, ideally no wider than five years. The age categories for which census and death tabulations are

available for India vary by age and are generally wider than 5 years, except under age 20, so the evaluation methods have to be adapted to deal with the information as it is available; the General Growth Balance method (Hill 1987) lends itself more easily to such adaptation than the Bennett-Horiuchi (1981) method, so we present results of the former.

We will argue that the population of India in the 1910s was essentially closed to migration and close to stationary – the annual growth rate for the decade was only 0.09%. Under this assumption, the birth rate and the death rate would be equal, as would the entry rate and death rate for any open-ended age group x+. One set of estimates of the completeness of death registration, based on the assumption of stationarity, is simply the set of ratios of death rates to entry rates for all available open-ended age groups (determined by the classification of age in the basic data). It can also reasonably be argued that the population should be regarded as stable, though with a very low growth rate, in which case the Brass Growth Balance (BGB) method can be applied, again to open-ended age groups; the problem with this argument is the potentially destabilizing effects of the influenza epidemic itself. Finally, it can be argued that the population should be regarded as non-stable, in which case the General Growth Balance (GGB) method is appropriate. We apply each of these three approaches, all of which make the same key assumption that the deaths that were registered were representative in terms of age and sex distribution of all deaths that occurred.

The results of the evaluation methods suggest that the completeness of death recording for Central Provinces and Berar is effectively complete. We therefore focus in on the data for this province to explore factors associated with excess mortality at the district level in a multi-level analysis.

Results

All India

Population Change Data

Table 2 shows the total population (all ages and ages 5 and over) of India by sex for the British-administered provinces and for the states as recorded by the 1901, 1911 and 1921 censuses (Census of India; 1901, 1911, 1921). Also shown is the shortfall between the expected 1921 population (given the population growth rate between 1901 and 1911) and the recorded 1921 population. It is this shortfall that has been interpreted as an estimate of the net demographic impact of the influenza epidemic. For India as a whole, the total is 17.8 million or 5.7% of the 1911 population; the losses both in absolute and relative terms are slightly larger for males than females. However, there is a large difference in the percentage loss between British-administered provinces and the states: 4.2% in the former and 11.1% in the latter, and the latter show larger female than male losses. At ages 5 and over, eliminating any possible effect of reduced numbers of births in the epidemic, the overall picture is rather different: total loss is only half the loss at all ages (8.9 million, 3.3% of the 1911 population), though still with an overall male disadvantage

and with a large difference in the percentage loss between the British-administered provinces (2.6%) and the states (5.7%); the states still show a reversal of the sex balance, with larger female than male losses.

The large differences between the all-ages and the ages 5+ analyses indicate that a substantial part of the population "loss" between 1911 and 1921 was the result of fewer births in the five years before the 1921 census rather than of excess influenza deaths. The annual series of registered births indicates that there was a dip in the number of births in 1918, a sharper dip in 1919, and a less than full recovery in 1920 and 1921. The ratios of the births in each year to the average number of births in the years 1913 to 1917 fell to 92% in 1918, and further to 78% in 1919, before recovering to about 85% in both 1920 and 1921. The decline in 1918 presumably reflects deaths of women in late pregnancy and possible stillbirths, while the drop in 1919 may reflect in addition effects of reduced conceptions resulting from deaths of husbands, reductions in conception rates among surviving couples and increased miscarriage rates. It is interesting to note that the sex ratio of registered births increased from around 107 males per 100 females to 108 in 1919. Continued low numbers of births in 1920 and 1921 presumably reflect persistent effects of reduced numbers of married couples.

Unadjusted registered death data

Unadjusted data (without evaluation or adjustment) can provide some indication of the severity and timing of the epidemic even if deaths are not completely reported. We calculate here an index of excess monthly mortality as the ratio of deaths in months from August 1918 to January 1919 relative to the average number of deaths in the same months in the preceding and following years. Assuming that completeness of death recording did not change over this period, these ratios will be unaffected by any under-reporting of deaths. Figure 1 plots the monthly ratios.

Figure 1 indicates the very uneven impact of the epidemic across India combined with little variation in timing of the epidemic. In terms of timing, Bombay clearly has the earliest impact, with some small increase in September and a peak in October, followed by Madras and Delhi, while Assam, Bihar (peaking in November and December) and United Provinces (with a significantly elevated level in December though a peak in November) appear to have been impacted last. In terms of level, Central Provinces and Berar peaked at a ratio of over 11, whereas for Bengal the ratio was scarcely higher than 2 in any month, with no clearly visible peak. Consistent with the contemporary observation that the initial infection spread from the Bombay Presidency is the early peak in that province and a rough association between the lag in the peak month of infection and the distance of the province from Bombay; Madras and Delhi do not fit this pattern, perhaps because of spread of infection independently to Madras by sea and directly overland to Delhi.

All-India results using adjusted registered death data

Assessment of Completeness of Death Registration

Between 1911 and 1921, the overall growth rate of the population of India (as recorded by the census counts) was close to zero: the male population grew by 1.3 per 1,000 per year, whereas the female population grew by 0.4 per 1,000. Above age 5, the male and female populations also grew very slowly, by 2.7 per 1,000 for males and 1.8 per 1,000 for females. It seems implausible that the population can have been far from stationary, or from stable with a very low rate of growth, for the intercensal period. However, growth rates for open-ended age intervals vary somewhat for males, reaching 1.1% for males above age 70 (though never exceeding 0.4% for females). Application of the Brass Growth Balance method (appropriate for a stable population) does not produce a perfectly linear set of points, but a robust regression line fitted through the entry and death rates above ages x (Figure 2) estimates stable growth rates of between 3 and 4 per 1,000 and similar levels of death registration completeness around 65% for both males and females. The alternative approaches described in the Methods section – General Growth Balance or assuming a stationary population – give very similar estimates of completeness.

We thus adopt 65% as our estimate of death registration completeness above age 5 for both male and female deaths; this is a somewhat higher figure than the 60% arrived at by Mills (1989). Table 3 shows recorded and adjusted (by a factor of 1.5) deaths at all ages and at ages 5 and over by sex for the years 1915 to 1920 (it would have been desirable to use deaths by month, but deaths by month and by age are not available in the published data). Using the adjusted numbers, excess deaths in 1918 and 1919 (calculated as deaths in those years minus "expected" deaths in a two-year period given deaths in 1915 to 1917 and 1920) are 6.9 million and 6.6 million for males and females respectively at all ages, and 4.8 and 4.1 million above age 5. These estimates above age 5 are about 2.5 million lower than those obtained from lost population growth (5.9 and 5.6 million for males and females respectively: Table 2); at all ages, the differences are much larger, but this is largely explained by the effect of reduced numbers of births on overall population growth. The "all ages" excess deaths will be somewhat below the true value because of the effect of reduced numbers of deaths under 5 resulting from fewer births in 1919 and 1920.

Central Provinces and Berar

Population Change Data

Table 2 shows the total population (all ages and ages 5 and over) of Central Provinces and Berar by sex for the British-administered areas and for the states as recorded by the 1901, 1911 and 1921 censuses. Also shown is the shortfall between the expected 1921 population (given the population growth rate between 1901 and 1911) and the recorded 1921 population. As before, this shortfall is interpreted as an estimate of the net demographic impact of the influenza epidemic. For Central Provinces and Berar as a whole, the total is an astonishing 2.9 million or 17.9% of the 1911 population; the losses both in absolute and relative terms are slightly larger for males than females. However,

there is a huge difference in the percentage loss between British-administered areas and the States: 16% in the former and 32% in the latter. At ages 5 and over, eliminating any possible effect of reduced numbers of births in the epidemic, the overall picture is rather different: total loss is less than half the loss at all ages (1.3 million, 9.7% of the 1911 population), though still with an overall male disadvantage; there is still a large difference in the percentage loss between the British-administered provinces (7.6%) and the states (25.2%).

As with the analysis for all India, the above analysis indicates that a substantial part of the population "loss" between 1911 and 1921 was the result of fewer births in the 5 years before the 1921 census rather than excess influenza deaths. The annual series of births indicates that, as for all India but rather more marked, there was a dip in the number of births in 1918, a sharper dip in 1919, and a less than full recovery in 1920 and 1921. The ratios of the births in each year to the average number of births in the years 1913 to 1917 fell to 90% in 1918, and 71% in 1919, before recovering to about 80% in both 1920 and 1921. The sex ratio at birth increased slightly in 1919 relative to the earlier years, but then stayed close to the higher level through 1921. Continued low numbers of births in 1920 and 1921 presumably reflect effects of reduced numbers of married couples.

Data on Registered Deaths

Assessment of Completeness of Death Registration

Between 1911 and 1921, the overall population of Central Provinces and Berar scarcely changed: the male population grew by 3 per 10,000 per year, whereas the female population shrank at the same rate. Above age 5, both populations grew very slowly, by 4 per 1,000 for males and 3 per 1,000 for females. It seems implausible that the population can have been far from stationary, or from stable with a very low rate of growth, for the intercensal period. However, growth rates for open-ended age intervals again vary quite considerably, from essentially zero above age 0 to 1.2% (males) and 0.8% (females) above age 60. These growth rates raise questions about the applicability of the Brass Growth Balance (BGB) method, shown in Figure 3(a), over and above the questions raised by the ragged nature of the points; however, using the General Growth Balance (GGB) method also produces a ragged set of points, and implausible intercepts which should estimate changes in census coverage from 1911 to 1921 (Figure 3(b)).

Rather than use either the BGB or the GGB methods in their original form, we adapt them to conform to our presumption that the population was either stationary or stable with a growth rate close to zero. First, we assume that the population is stationary, and average the ratios of entry rates to death rates for ages from 5 and over to 60 and over; the result estimates death registration completeness as 98 percent for both males and females. Second, we assume that the population at ages 5 and over is stable, and growing at four per 1,000 (males) and three per 1,000 (females); We add these growth rates to the death rates, and fit a line to the entry rates x+ versus the death rates plus constant growth rate, forcing the line to pass through the origin (the fitted lines are shown in Figure 3(a)). The resulting slopes estimate completeness of death registration (relative to population

coverage) of 108% (males) and 105% (females). Though fits are by no means perfect, it seems reasonable to conclude that registration of deaths in the 1910s in Central Provinces and Berar was approximately complete.

Table 4 shows the registered deaths by sex (all ages and 5+) for the years 1915 to 1920. Influenza deaths are estimated as the number of deaths in 1918 and 1919 minus the two-year average number for the years 1915 to 1917 and 1920. At all ages, the numbers are 485 thousand male deaths and 488 thousand female deaths, far lower than the estimates of 1.465 million and 1.412 million from "lost" population growth in Table 2. For ages 5 and over, the influenza deaths are estimated as 372 thousand for males and 382 thousand for females, still much smaller than the "lost" population growth estimates of 687 thousand and 617 thousand respectively.

Excess Deaths by Age and Sex

Data by month of death are not available by age and sex, but annual data are available. The epidemic in Central Provinces and Berar was largely confined to the last months of 1918, but with some deaths spilling into 1919; we calculate the excess deaths by (broad) age groups and sex in 1918 and 1919 relative to the average for 1917 and 1920. Figure 4 shows the ratios of excess deaths by sex and age group. The ratios for both males and females rise to a peak for ages 20-29, being substantially lower for children and the elderly, a similar pattern to that observed in countries with more developed statistical systems (Crosby, 2003). The ratios are also slightly higher for females than for males, at least in the central adult ages.

Excess Deaths by District

Table 5 shows by district the deaths in the period August 1918 to July 1919, the average number for the corresponding months of the preceding and following year, the number of excess deaths, and the excess death rate (based on the estimated district population in 1918 assuming exponential growth between 1911 and 1921, adjusting the recorded 1921 population for the excess deaths occurring in 1918-19), by district. The total number of excess deaths is estimated at 909,000, the death ratio as 2.6 (note that this figure is much lower than the ratio for Central Provinces in Figure 1 because it covers an entire 12 month period, during most of which there were no excess deaths), and the overall excess death rate as 62 per 1,000 population. There is considerable variation both in the excess death ratio and the excess death rate by district; the excess death rate varies from 113 per 1,000 population in Damoh district (a staggeringly high figure, over 10 percent of the population died as a result of the influenza epidemic) with two other districts above 90 per 1,000, to less than 40 per 1,000 in Bilaspur and Rajpur.

Unfortunately, data on deaths by day or week are not available, but we can approximate the date of the mortality peak by assuming that excess deaths occurred in the middle of the month and calculating the average date of the excess deaths. Results are shown in Table 5, dates being shown as month and day in 1918. There is very little variation in the

average date of peak mortality, varying only from the middle of October 1918 in Nagpur (the provincial capital) to the middle of November in Bilaspur. There is no association whatever between the severity of the mortality peak and the date of the peak, but the epidemic clearly moved from the Southwest, with peaks in October, to .Northeast, with peaks in November.

Given the substantial variation in the severity of the peak mortality by district, it is of interest to explore possible associations with district characteristics. We are limited in terms of such characteristics by the data available for the early 20th century, mostly from the 1911 census. The characteristics we explore from that census are: baseline death rate, density in persons per square mile, percent urban, the sex ratio (females per 1,000 males), literacy (of males, females, and both sexes combined in the age group 15-19, per 1,000), percent of the population Hindu, the percent of the population supported by agriculture, and two indicators of migration: immigration, the number per 1,000 born in non-contiguous districts, and emigration, the number per 1,000 born in the district living in other non-contiguous districts. We also included some additional variables from the 1921 Statistical Abstract: average district rainfall in inches, percent of arable land irrigated, and the percent of arable land under specified crops (wheat, rice and cotton).

An initial pass through the data examined the bivariate associations between the outcome variable (excess death rate 1918-19 by district) and each independent variable. Variables that failed to reach a bivariate significance of 20 percent were: baseline death rate, in-migration, population density in 1911, percent of population supported by agriculture, percent of arable land irrigated, percent of arable land under wheat or under cotton, percent Hindu, literacy of males or females or both sexes aged 15-19. A multivariate model was then estimated, including only variables that reached the 20 percent threshold: sex ratio of the population, emigration, rainfall and the percent of arable land under rice. In this model, the variables other than percent of arable land under rice remained significant, so a final model was estimated including only the first three variables. Results are shown in Table 6.

The three remaining variables are highly significant, and together account for approximately two-thirds of the variance in the excess death rate. The negative coefficient on the sex ratio is consistent with the higher estimated losses from the analysis of population shortfall, but not with the rather similar excess mortality estimated from registered deaths and the greater relative effect for females than males in Figure 4. We have no explanation for the negative association with emigration level. The positive association with rainfall may suggest that the influenza virus was more easily transmitted in damp than dry settings (though this would hardly explain the relatively low level of excess mortality in Bengal), but more probably that bacterial pneumonia consequent upon prior influenza infection was more common in damper areas, as suggested by Mills (1989).

Discussion and Conclusion

The mortality effects of the 1918 influenza epidemic appear to have been higher in India than anywhere else on the planet. We use a variety of demographic methods to assess the magnitude of the impact, Though the results are not consistent, it seems clear that the number of excess deaths from the epidemic was lower than the estimates of impact by Davis (1955) of 18.5 to 22.5 million, or those by Mills (1989) of 17.4 to 18.5 million. Our estimate of excess deaths above age 5 is in the range of 8.9 to 11.4 million, depending on whether one relies on population shortfall or adjusted registered deaths, with perhaps another two million influenza deaths under the age of 5, for a total of 11 to 13.5 million or so.

It is clear that the epidemic swept across India in a matter of three months, and that the impact varied widely, being worst in the Bombay Presidency and Central Provinces and Berar. Multivariate analysis of district-level differentials in excess mortality in Central Provinces identified some significant associations (with rainfall, emigration, and sex ratio), but no association with demographic characteristics such as underlying mortality or density or with social indicators such as literacy. It remains unclear whether the district variations were the result of differential susceptibility due to immune system differences or other factors that might predispose to high mortality. There was a famine in Berar in 1918 as a result of failure of the monsoon, with annual rainfall scarcely half its usual level, but Berar was not excessively hard-hit by the epidemic.

Some interesting patterns emerge from the data. First, the age pattern of excess mortality risk follows that observed in European countries of peaking in the age range 20 to 29. On the other hand, sex differences are not consistent across data sources. It is clear that the areas under British administration suffered less excess mortality than the states, though we have no hypothesis to explain this finding.

Various theories have been put forward for variations in the severity of the influenza epidemic in India. King (1922) notes an inverse association in the Punjab with altitude. Gill (1928) argues that diurnal temperature range is key (and explains the association with altitude). His argument is that the combination of low temperature and high humidity is conducive to the spread of what he refers to as the influenza bacillus via droplets, and that a high diurnal temperature range implies a period once every 24 hours in which temperature will be low and therefore humidity high. .Mills (1989) examines this theory in the context of the Bombay Presidency, and finds support for it, though suggesting that the association of high mortality and large diurnal temperature range works through increased risk of pneumonic complications of influenza rather than transmission of infection. Regardless of the mechanism, the association we find between excess mortality and rainfall at the district level suggests a role for relative humidity, and the most severely affected districts of Central Provinces are those with a November diurnal temperature range of 25 $^{\circ}$F to 30 $^{\circ}$F, basically the northern and western districts, and those least affected are those with diurnal temperature ranges of 20 $^{\circ}$F to 25 $^{\circ}$F in the South-east of the province. One empirical observation not explained by the diurnal temperature range, however, is the relative severity of the epidemic in the states relative to the areas administered by the British.

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Table 1: Excess Death Rate (per 1,000 Population) 1918-1920 Relative to Average 1915-1917, 1921-1923; Selected Developing Countries

Americas	Crude Death Rate Excess 1918-20 per 1,000 Pop	Africa	Crude Death Rate Excess 1918-20 per 1,000 Pop	Asia	Crude Death Rate Excess 1918-20 per 1,000 Pop
Argentina	1.8	Egypt*	6.0	Cyprus	0.8
Chile	1.0	Mauritius	10.2	India	14.6
Costa Rica	7.4	South Africa (whites)	3.3	Philippines	9.4
Guyana	6.9			Singapore	5.5
Jamaica	3.2			Sri Lanka	5.6
Puerto Rico	2.6			Taiwan	4.8
Trinidad and Tobago	1.7				
Uruguay	1.0				

* Relative to Average 1917, 1921-1923 only
Source: Murray et al. (2006)

Table 2: Population Growth 1901 to 1921: India and Central Provinces and Berar, with Estimated Population Loss from the 1918 Influenza Epidemic.

Census Year	Sex	India			Central Provinces and Berar		
		Provinces	States	Total	Province	States	Tot
		All Ages					
	Male	117,483	31,938	149,421	5,937	812	6,749
	Female	113,776	30,180	143,956	6,055	819	6,874
1901	Total	231,259	62,118	293,377	11,992	1,631	13,623
	Male	124,708	35,293	160,001	6,930	1,054	7,984
	Female	119,225	33,417	152,642	6,980	1,063	8,043
1911	Total	243,933	68,710	312,643	13,910	2,117	16,027
	Male	126,872	35,209	162,081	6,951	1,029	7,980
	Female	120,131	33,138	153,269	6,961	1,038	7,999
1921	Total	247,003	68,347	315,350	13,912	2,067	15,979
	Male	5,505	3,791	9,249	1,138	339	1,465
	Female	4,804	3,863	8,583	1,085	342	1,412
1921 Shortfall	Total	10,309	7,655	17,832	2,223	681	2,877
	Male	4.4%	10.7%	5.8%	16.4%	32.2%	18.3%
	Female	4.0%	11.6%	5.6%	15.5%	32.1%	17.6%
1921 Shortfall as % of 1911 Population	Total	4.2%	11.1%	5.7%	16.0%	32.2%	17.9%
		Age 5 and Over					
	Male	102333	28352	130,661	5221.2	695.8	5917
	Female	98164	26523	124,660	5309.2	692.1	6001.3
1901	Total	200,497	54,875	255,321	10,530	1,388	11,918
	Male	108374	30391	138,766	5851.7	876.4	6728.1
	Female	102407	28360	130,767	5851.9	873.3	6725.2
1911	Total	210,781	58,751	269,533	11,704	1,750	13,453
	Male	111699	30897	142,596	6082.5	880.4	6962.9
	Female	104429	28668	133,100	6033.8	885.3	6919.1
1921	Total	216,128	59,56	275,69	12,116	1,766	13,882

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	Male	3,073	1,680	4,778	476	223	687
	Female	2,404	1,656	4,073	416	217	617
1921 Shortfall	Total	5,477	3,336	8,851	892	440	1,305
	Male	2.8%	5.5%	3.4%	8.1%	25.5 %	10.2%
	Female	2.3%	5.8%	3.1%	7.1%	24.8 %	9.2%
1921 Shortfall as % of 1911 Population	Total	2.6%	5.7%	3.3%	7.6%	25.2 %	9.7%

Table 3 : Registered and Adjusted Deaths by Year, and Excess 1918 and 1919: All India

	Age Range	1915	1916	1917	1918	1919	1920	Excess 1918 and 1919
Unadjusted								
Males	Total	3696	3602	4045	7606	4575	3851	4584
	5 and over	2153	2035	2331	5365	3036	2446	3919
Females	Total	3462	3330	3759	7281	4139	3504	4393
	5 and over	2051	1906	2178	5216	2707	2228	3743
Adjusted								
Males	Total	5544	5403	6068	11408	6863	5777	6875
	5 and over	3229	3052	3497	8048	4554	3669	5879
Females	Total	5193	4994	5638	10922	6209	5255	6590
	5 and over	3076	2859	3267	7825	4061	3341	5615

Table 4: Registered and Adjusted Deaths by Year, and Excess 1918 and 1919: Central Provinces and Berar

	Age Range	1915	1916	1917	1918	1919	1920	Excess 1918 and 1919
Unadjusted								
Males	Total	259180	290085	262788	721221	316708	293463	485171
	5 and over	110818	143093	134950	475643	177956	174518	371910
Females	Total	240502	262854	238926	706629	284412	264494	487653
	5 and over	109055	135915	126282	487450	160627	160332	382285

Table 5: Excess Deaths and Death Rates by District: Central Provinces and Berar, August 1918 to July 1919

District	Deaths		Excess Deaths			
	08/18 to 07/19	Average 08/17 to 07/18 and 08/19 to 07/20	Number	Ratio	Crude Rate per 1,000 1918 Population*	Average Date of Peak (Month)
Nagpur	67936	33423	34513	2.033	41.9	10.5
Bhandara	61603	27126	34478	2.271	46.9	10.9
Wardha	45957	15458	30499	2.973	62.8	10.6
Chanda	72714	23205	49509	3.134	70.5	11.2
Balagat	46274	17259	29015	2.681	55.4	10.9
Jubbulpore	83890	40027	43863	2.096	56.3	11.0
Saugar	71663	22307	49357	3.213	86.9	11.1
Damoh	52983	16029	36955	3.306	113.3	11.0
Seoni	46704	17612	29093	2.652	76.1	11.3
Mandla	51155	11917	39238	4.293	93.4	11.6
Hoshangabad	53573	19401	34173	2.761	72.1	10.9
Nimar	45114	18478	26636	2.441	64.1	10.9
Narsinghpur	38149	15400	22750	2.477	68.0	11.1
Betul	51278	13937	37342	3.679	93.7	11.2
Chhindwara	43722	20686	23037	2.114	44.7	11.2
Rajpur	114090	57671	56419	1.978	39.5	11.2
Bilaspur	83812	45037	38776	1.861	31.3	11.4
Drug	73031	35717	37315	2.045	47.9	11.1
Amraoti	96470	29967	66503	3.219	74.8	10.6
Yeotmal	100359	24165	76194	4.153	89.3	10.7
Akola	96244	31033	65211	3.101	77.2	10.5
Buldana	75215	26823	48393	2.804	66.6	10.4
Total	1471936	562673	909264	2.616	62.1	10.9

* See text for explanation

Table 6: Regression of excess mortality rate by district on other district characteristics: Central Provinces and Berar

Variable	Coefficient	p>|t|
Sex ratio of district population (females per 1000 males)	-0.554	0.000
Emigration	-0.616	0.001
Average rainfall (inches)	2.160	0.001
Cosntant	545.7	0.000

N = 22 R^2 = 0.66

Figure 1: Registered deaths by month relative to average numbers in the preceding and following year by province: August 1918 to March 1919.

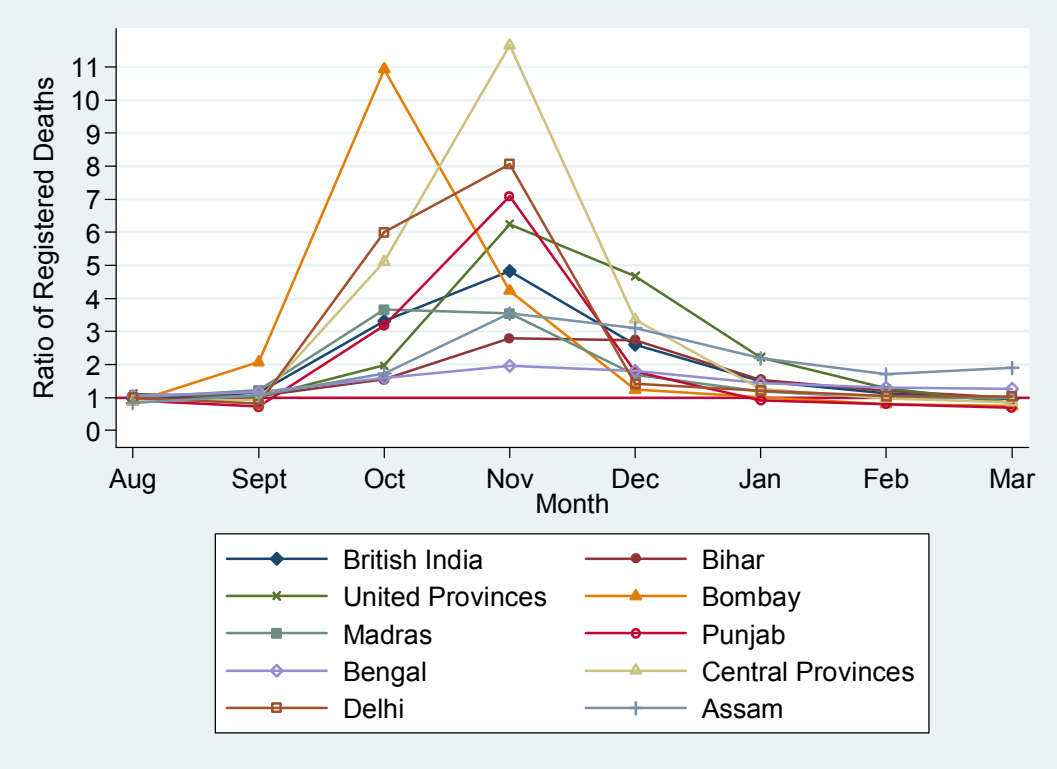
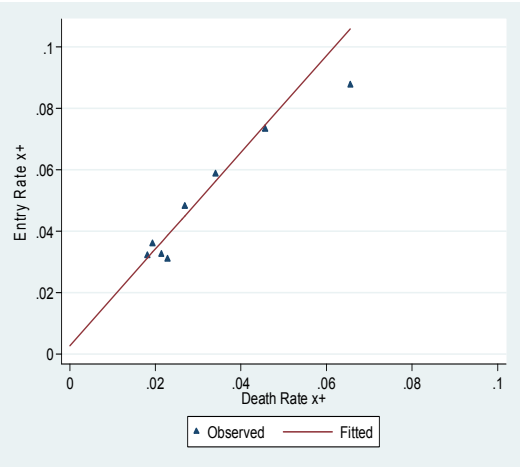


Figure 2: Application of Brass Growth Balance Method: All India, 1911 to 1921

a) Males



b) Females

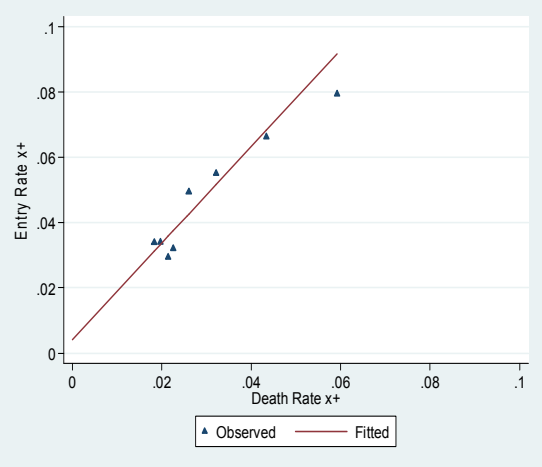
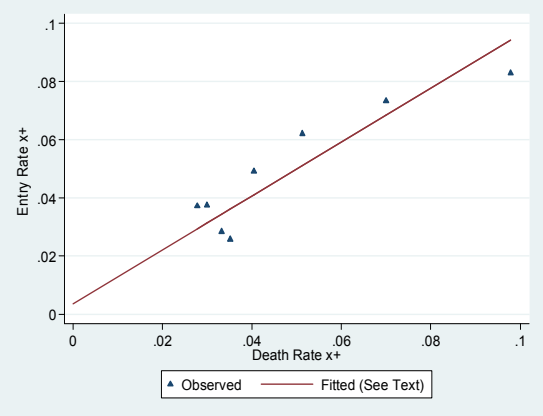


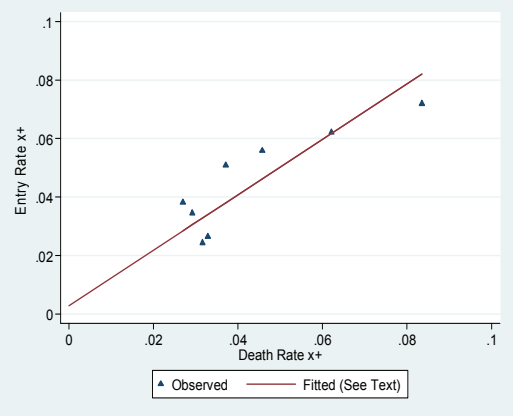
Table 3: Plots of Entry Rates (Brass Growth Balance) or Entry rates minus Growth Rates (General Growth Balance) x+ against Death Rates x+: Central Provinces and Berar, 1911 to 1921

a) Brass Growth Balance

Males

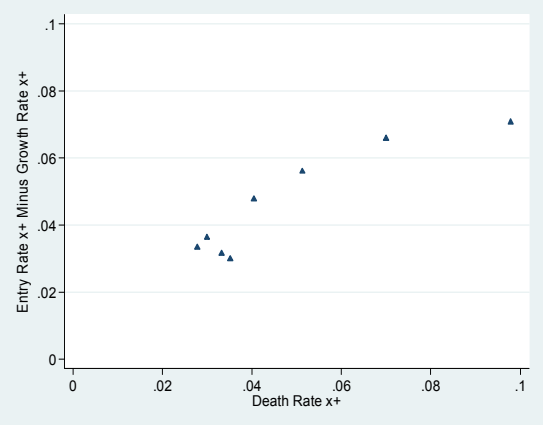


Females



b) General Growth Balance

Males



Females

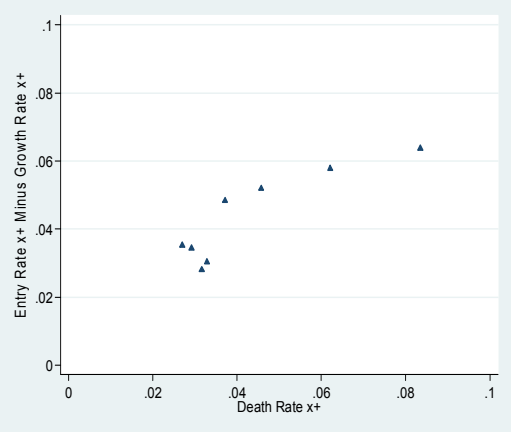


Figure 4: Excess Deaths by Sex and Age Group in 1918-19 Relative to the Average for 1917 and 1920: Central Provinces and Berar