Supplementary Material

This has been provided by the authors to provide readers with additional information about the study.

Supplement to:

The impact of diabetes on productivity in India.

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Mortality rates

Age- and sex-specific all-cause mortality data for India were derived from the 2017 Institute for Health Metrics and Evaluation – Global Health Data Exchange database [1]. Mortality rates in those with and without diabetes were estimated based on age- and sex-specific diabetes prevalence and the relative risk (RR) of all-cause mortality associated with diabetes in India, derived from the Chennai Urban Rural Epidemiology (CURES) Study of Asian adults with and without diabetes [2]. The CURES reported age-group (20-39, 40-59, 60-79, and 80-99 years) and sex-specific death rates in those with and without diabetes. The RR for people aged 40-59, 60-79 and 80-99 were plotted and a power function was fitted *(R^2 = 0.89 for men, R^2= 0.99 for women)* to determine RR parameters for single year of age *(RR for men = 439.41 * $age^{-1.306}$, RR for women = 857.5 * $age^{-1.367}$).* The RR for people aged 20-39 years was not included due to the small number of deaths in this age group. N.B. The RR for those aged over 60 years were included in order to determine the line of best fit and therefore estimate RR for single year of age. The RR parameters were not adjusted for other co-morbidities. All-cause mortality rates were obtained for five-year age bands and extrapolated using exponential functions to provide rates for age in single years *(mortality rates for men = 0.0002050892 * $exp^{0.075392713*age}$, R^2 = 0.99; mortality rates for women = 0.0001380261 * $exp^{0.0776583797*age}$, R^2= 0.9),* assuming that the rate for each five-year age group applied to people in the midpoint of that age band.

We applied temporal trends in population mortality risks across the model time horizon using the annual reduction in population mortality risk from the United Nations World Population Prospects (UN WPP) forecast (1% per year) [3]. Annual age-and sex-specific mortality rates were applied in each yearly cycle and deaths were assumed to have occurred at the midpoint of the year.

Calculation of annual mortality rates in those with and without diabetes in the Indian population by sex- and age-group was based on the following formula:

*Mortality rate in those without diabetes = Total mortality / [Prevalence of diabetes * RR + (1 – Prevalence of diabetes)]*

The mortality rate for those with diabetes was based in the following formula:

*Mortality rate in those with diabetes = Mortality rate in those without diabetes * RR*

Where:

Total Mortality = Total deaths in population / Total Population

RR = Relative risk of all-cause mortality in those with diabetes compared to those without diabetes

Labour force participation

Data on age- and sex-specific population labour force participation rates in India were derived from the 2017 International Labour Organisation (ILO) estimates [4]. In 2017, 78.7% of men and 23.8% of women contributed to the labour force. Labour force participation was lowest in those aged 20-24 years in both sexes (68.6% in men; and 17.6% in women). Labour force participation was highest in those aged 35-39 years (98.9%) in men and aged 40-44 years (34%) in women, respectively. The mid-point of each age-group was plotted against the respective labour force participation rates, and polynomial functions were fitted to determine rates by single year of age using the following formulae:

Labour force participation for men = $-0.0624*age^2 + 4.9881*age + 1$, $R^2 = 0.86$

Labour force participation for women = $-0.041*age^2 + 3.6106*age - 44.649$, $R^2 = 0.96$

Population labour force participation rates in women are low (24%), which may be due to their increased participation in unpaid work such as carer duties. However, due to a lack of available data on women's participation in unpaid work, and the impact that diabetes may have on this, our analysis focuses on the productivity impacts in employed persons only.

To account for differences in labour force participation in people with and without diabetes, diabetes-related labour force dropouts were drawn from a recent meta-analysis. Bommer et al reported labour force dropouts for South Asia, which ranged between 7.0% in those aged 20-40 years and 12.8% in those over 40 years in women, and 5.2% and 8.3% in men, respectively [5]. Diabetes-related labour force dropout was defined as the employment probability shortfall of people with diabetes compared to people without diabetes. The observed marginal effects were set in relation to the study-specific labour-force participation rates and assumed that the unemployment rate was the same in people with and without diabetes. The age-group and sex-specific labour force dropout rates were plotted, and the following polynomial functions were used to determine labour force dropout rates for single year of age:

*Diabetes-related labour force drop-out for men = -0.002*age^2 + 0.2749*age - 0.8406, R^2 = 0.81*

*Diabetes-related labour force drop-out for women = -0.0038*age^2 + 0.5143*age - 4.3017, R^2 = 0.81*

The labour force participation rates in those with diabetes were derived by applying the diabetes-related labour force dropout rates to the age- and sex-specific population labour force participation rates in India, obtained from the 2017 ILO estimates [4]. The labour force participation rates in those without diabetes were assumed to be equivalent to the population

estimates. In the model, we assumed that all employees worked full-time due to the lack of evidence on the allocation of the labour force into full-time and part-time employment by disease status. In the model, years of life lived in the labour force were calculated as years of life lived by the cohort multiplied by the labour force participation rate.

Labour force participation rate in people without diabetes = Population labour force participation rate in India

Labour force participation rate in people with diabetes = Population labour force participation rate in India - diabetes-related labour force dropout

Productivity-adjusted life years (PALYs)

PALYs are calculated using years of life lived and condition-specific productivity indices and adjusted for labour force participation rates where possible. The following formula is used to determine PALYs:

*PALYs = years of life lived in the labour force * productivity index*

where

Years of life lived in the labour force = years of life lived by labour force participation rates

$$\text{Productivity index} = \frac{\text{Total working days in a year – absenteeism days – presenteeism days}}{\text{Total working days in a year}}$$

Labour force participation rates were specific for people with and without diabetes. For people without diabetes, labour force participation rates were equivalent to population labour force participation rates (derived from 2017 ILO estimates). For people with diabetes, population

labour force participation rates were adjusted for diabetes-related labour force dropout (see the detailed description above).

The productivity index considers both absenteeism and presenteeism data, where available. For this study, absenteeism and presenteeism data were not available for people with and without diabetes. As such, we assumed that absenteeism and presenteeism did not exist in people without diabetes, and therefore people without diabetes had a productivity index of 1. Absenteeism and presenteeism data for people with diabetes were drawn from a meta-analysis by Bommer et al who provided estimates for South Asia. This study was chosen due to the high risk of bias with presenteeism data in a study in India. Bommer et al estimated absenteeism to be 7.5 days per year in both men and women [5], which, as a proportion of the 234-total number of working days per year in India, including public holidays, represents a 3.2% reduction in productivity. Diabetes-related presenteeism was 0.6% in men and 1.0% in women [5]. Hence, the overall diabetes-associated reduction in productivity due to absenteeism and presenteeism were assumed to be 3.8% in men (productivity index = 1 – 0.038 = 0.962) and 4.2% in women (productivity index = 1 – 0.042 = 0.958).

PALYs were ascribed an economic value in terms of gross domestic product (GDP). Data on the GDP per person employed were derived from the 2019 Organisation for Economic Co-operation and Development (OECD) Compendium of Productivity Indicators [6]. In India, in 2017, the GDP per person employed was USD 17,546 (INR 1,200,008 and PPP 66,198, determined using the OECD exchange and purchasing power parity (PPP) rates assuming USD constant prices, 2011) [7]. We assumed that the economic value of each PALY was equivalent to the annual GDP per person employed in India. Hence, each PALY was equal to USD 17,546.

An annual growth rate in GDP of 7.2% was applied for each year in the model [8]. The economic costs (GDP) lost to diabetes were determined as the difference in costs (and PALYs) for the two modelled simulations. As per the Methods section of the main text, first, the number of PALYs lived and costs were estimated for the population with diabetes in India, followed up over their working lifetime. Then, follow-up was re-simulated hypothetically assuming that they did not have diabetes (diabetes did not exist), and mortality rates and productivity impacts were updated to reflect people who did not have diabetes.

Supplementary Table 1: Description and source of key data used as inputs for the life table models.

Model inputs and data description	Data source
Population: The 2017 Indian adult population, stratified by sex- and five-year age groups	International Diabetes Federation: IDF Diabetes Atlas (8th edition) [9].
Prevalence of diabetes: Diabetes prevalence in India in 2017, stratified by sex- and five-year age groups	International Diabetes Federation: IDF Diabetes Atlas (8th edition) [9].
Mortality rates: All-cause mortality rates of India in 2017, stratified by sex- and five-year age groups	Institute for Health Metrics and Evaluation. GHDx – Global Health Data Exchange [1].
Relative Risk (RR) of all-cause mortality associated with diabetes	Anjana RM, Unnikrishnan R, Mugilan P, Jagdish PS, Parthasarathy B, Deepa M, et al. Causes and predictors of mortality in Asian Indians with and without diabetes-10-year follow-up of the Chennai Urban Rural Epidemiology Study (CURES - 150). PLoS One. 2018;13(7): e0197376-e [2].
Temporal trends in population mortality rate	Projected average annual proportional reduction in adult mortality in India (1.0%) from the United Nations World Population Prospects (UNWPP) forecast [3].
Population labour force participation: Labour force participation in India in 2017, stratified by sex- and five-year age groups	International Labour Office: ILO Labour force estimates and projections: 1990- 2030 [4].
Diabetes- associated productivity losses: Labour force participation dropouts, absenteeism and presenteeism in those with diabetes	Bommer C, Heesemann E, Sagalova V, Manne-Goehler J, Atun R, Barnighausen T, et al. The global economic burden of diabetes in adults aged 20-79 years: a cost-of-illness study. The Lancet Diabetes & Endocrinology. 2017;5(6):423-30 [5].
Gross domestic product: The GDP per person employed full-time (EFT) in India in 2019.	Organisation for Economic Co-operation and Development (OECD) Compendium of Productivity Indicators [6].
Temporal trends in GDP	The World Bank [8].

Supplementary Table 2: Annual mortality rates in the total population, people with diabetes and people without diabetes in India in 2017 by single year of age for men and women

Age (years)	Mortality rates per person per year					
	Men			Women		
	Total population	People without diabetes	People with diabetes	Total population	People without diabetes	People with diabetes
20	0.09%	0.09%	0.79%	0.07%	0.06%	0.82%
21	0.10%	0.10%	0.80%	0.07%	0.06%	0.84%
22	0.11%	0.11%	0.81%	0.08%	0.07%	0.85%
23	0.12%	0.11%	0.83%	0.08%	0.07%	0.87%
24	0.13%	0.12%	0.85%	0.09%	0.08%	0.89%
25	0.14%	0.13%	0.87%	0.10%	0.08%	0.87%
26	0.15%	0.14%	0.85%	0.10%	0.09%	0.86%
27	0.16%	0.14%	0.85%	0.11%	0.09%	0.85%
28	0.17%	0.15%	0.85%	0.12%	0.09%	0.85%
29	0.18%	0.16%	0.85%	0.13%	0.10%	0.86%
30	0.20%	0.17%	0.86%	0.14%	0.11%	0.87%
31	0.21%	0.18%	0.88%	0.15%	0.11%	0.88%
32	0.23%	0.19%	0.90%	0.17%	0.12%	0.90%
33	0.25%	0.20%	0.92%	0.18%	0.13%	0.92%
34	0.27%	0.21%	0.94%	0.19%	0.14%	0.94%
35	0.29%	0.23%	0.97%	0.21%	0.15%	0.97%
36	0.31%	0.25%	1.00%	0.23%	0.16%	1.00%
37	0.33%	0.26%	1.04%	0.24%	0.17%	1.04%
38	0.36%	0.28%	1.08%	0.26%	0.18%	1.07%
39	0.39%	0.31%	1.12%	0.29%	0.19%	1.12%
40	0.42%	0.33%	1.17%	0.31%	0.21%	1.16%
41	0.45%	0.35%	1.22%	0.33%	0.23%	1.21%
42	0.49%	0.38%	1.27%	0.36%	0.24%	1.26%
43	0.52%	0.41%	1.33%	0.39%	0.26%	1.32%
44	0.57%	0.44%	1.39%	0.42%	0.28%	1.38%
45	0.61%	0.48%	1.46%	0.45%	0.31%	1.45%
46	0.66%	0.52%	1.53%	0.49%	0.33%	1.52%
47	0.71%	0.56%	1.61%	0.53%	0.36%	1.59%
48	0.76%	0.61%	1.70%	0.57%	0.39%	1.67%
49	0.82%	0.66%	1.79%	0.62%	0.42%	1.76%
50	0.89%	0.71%	1.88%	0.67%	0.45%	1.86%
51	0.96%	0.77%	1.99%	0.72%	0.49%	1.96%
52	1.03%	0.83%	2.10%	0.78%	0.53%	2.06%
53	1.12%	0.90%	2.21%	0.85%	0.58%	2.18%
54	1.20%	0.97%	2.34%	0.91%	0.63%	2.30%
55	1.30%	1.05%	2.47%	0.99%	0.68%	2.43%
56	1.40%	1.14%	2.62%	1.07%	0.74%	2.57%
57	1.51%	1.24%	2.77%	1.15%	0.80%	2.72%
58	1.63%	1.34%	2.94%	1.25%	0.86%	2.88%

59	1.75%	1.45%	3.11%	1.35%	0.94%	3.05%
60	1.89%	1.58%	3.30%	1.46%	1.02%	3.23%

Supplementary Table 3: Age- and sex-specific estimates for the total population and for those living with diabetes estimated using diabetes prevalence in India in 2017

Age group (years)	Men			Women		
	Total population[a]	Diabetes prevalence (%)[b]	Number of men with diabetes	Total population[a]	Diabetes prevalence (%)[b]	Number of women with diabetes
20 - 24	63,038,330	0.8	493,534	56,826,890	1.1	651,055
25 - 29	59,884,270	1.9	1,113,700	54,834,810	2.2	1,197,928
30 - 34	55,900,280	3.9	2,181,156	51,856,790	3.9	2,010,510
35 - 39	49,559,820	7.1	3,531,658	46,356,300	6.3	2,923,065
40 - 44	43,388,300	11.2	4,877,996	40,891,780	9.3	3,805,820
45 - 49	38,042,460	15.4	5,857,183	36,131,870	12.5	4,500,078
50 - 54	33,069,590	18.6	6,139,740	31,710,240	15.2	4,822,147
55 - 59	28,032,100	20.0	5,607,589	27,191,240	17.1	4,648,146
Total	370,915,150	8.0	29,802,556	345,799,920	7.1	24,558,749

a & b: Age- and sex-specific population estimates and diabetes prevalence estimates were based on data from the 2017 IDF Diabetes Atlas [9]. The number of men and women with diabetes were calculated based on diabetes prevalence, however due to rounding of data presented in this table, values may not exactly match.

Supplementary Table 4: Sensitivity and scenario analyses to evaluate the impact of uncertainties surrounding key input parameters on PALYs lost attributable to diabetes, and the associated economic loss, over the working lifetime the Indian working-age population

	PALYs lost due to diabetes	% change in PALYs lost compared to base case	GDP lost (USD, trillion)	GDP lost per person with diabetes (USD)
Base case	**89,049,206**		**2.6**	**57,531**
1. Productivity indices lower uncertainty bound [a]	92,105,954	3.43	2.7	59,346
2. Productivity indices upper uncertainty bound [a]	86,225,459	- 3.17	2.5	55,855
3. Labour force dropout lower uncertainty bound [b]	100,842,401	13.24	2.9	64,545
4. Labour force dropout upper uncertainty bound [b]	77,256,012	- 13.24	2.3	50,517
5. Lower uncertainty bound of all-cause mortality risk associated with diabetes [c]	76,272,344	- 14.35	2.2	48,055
6. Upper uncertainty bound of all-cause mortality risk associated with diabetes [c]	99,691,202	11.95	2.9	65,241
7. Temporal trend in population mortality risk is doubled to a 2% reduction per year [d]	88,060,351	- 1.11	2.5	56,683
8. No temporal trend in population mortality risk [d]	90,125,258	1.21	2.6	58,456
9. Annual GDP growth rate is doubled to 14.4% per year [e]	89,049,206	0.00	3.6	80,200
10. Annual GDP growth rate is halved to 3.6% per year	89,049,206	0.00	2.1	46,196
11. No temporal trend in GDP [e]	89,049,206	0.00	1.6	34,861
12. Annual discount rate increased to 5%[f]	75,625,399	- 15.07	2.1	46,728
13. Annual discount rate reduced to 1.5% [f]	102,226,520	14.80	3.1	68,543

[a]Apply (1) a 25% reduction and (2) a 25% increase in absenteeism and presenteeism estimates

[b] Apply (3) a 25% reduction and (4) a 25% increase in diabetes-related labour force dropout estimates

[c] Apply (5) the lower bound and (6) the upper bound of the 95% confidence interval around the estimate of RR of all-cause mortality associated with diabetes

[d] Apply (7) double the annual reduction in mortality risk to 2% per year and (8) no temporal trend in population mortality risk

[e] Apply (9) double the annual growth rate in GDP to 14.4% per year, (10) halve the annual growth rate in GDP to 3.6% per year and (11) no temporal trend in GDP across the model. These sensitivity analyses do not affect the number of PALYs lived but do affect their assumed value and therefore the resulting GDP lost

[f] Apply an annual discount rate (12) increased to 5% (in line with the WHO standard annual rate) and (13) reduced to 1.5%

Supplementary Material References:

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