The Impact of Diabetes on Productivity in India

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

Diabetes increases the risk of premature mortality and considerably impacts on work productivity. We sought to examine the impact of diabetes in India, in terms of excess premature mortality, years of life lost (YLL), productivity-adjusted life years (PALYs) lost, and its associated economic impact.

RESEARCH DESIGN AND METHODS

A life table model was constructed to examine the productivity of the Indian working-age population currently aged 20–59 years with diabetes, followed until death or retirement age (60 years). The same cohort was resimulated, hypothetically assuming that they did not have diabetes. The total difference between the two cohorts, in terms of excess deaths, YLL and PALYs lost reflected the impact of diabetes. Data regarding the prevalence of diabetes, mortality, labor force drop-outs, and productivity loss attributable to diabetes were derived from published sources.

RESULTS

In 2017, an estimated 54.4 million (7.6%) people of working-age in India had diabetes. With simulated follow-up until death or retirement age, diabetes was predicted to cause 8.5 million excess deaths (62.7% of all deaths), 42.7 million YLL (7.4% of total estimated years of life lived), and 89.0 million PALYs lost (23.3% of total estimated PALYs), equating to an estimated Indian rupee 176.6 trillion (U.S. dollars 2.6 trillion; purchasing power parity 9.8 trillion) in lost gross domestic product.

CONCLUSIONS

Our study demonstrates the impact of diabetes on productivity loss and highlights the importance of health strategies aimed at the prevention of diabetes.

Diabetes represents a growing challenge, and in 2000, India had the world's largest population living with diabetes (~31.7 million) followed by China (~20.8 million) (1). Since then, the number of people living with diabetes has continued to grow, with an estimated 65 million people living with diabetes (or an estimated prevalence of 7.7%) in 2016 (2) and 77 million people aged 20 to 79 years living with diabetes (or an estimated prevalence of 8.9%) in 2019 (3). Although prevalence of diabetes is highest in people of older age, the impact on younger adults is growing (4). Luhar et al. (5) estimated that the lifetime risk of developing diabetes among Indian metropolitans at 20 years of age was 64.6% among women and 55.5% among men. The remaining lifetime risk at 40 years and 60 years of age was 59.2% and 37.7% among women and 47.3% and 27.5% among men, respectively (5). Moreover, there is

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evidence to suggest that early onset of type 2 diabetes is more common in India due to a strong genetic component, compared with other Asian countries (6), which may be a reason for earlier age of onset. In India, the prevalence of diabetes is rising among younger age populations, as supported by two major epidemiology studies, the National Urban Diabetes Study (NUDS) and the Chennai Urban Rural Epidemiology Study (CURES) (7,8). Mohan et al. (8) compared secular trends in diabetes prevalence in Chennai, India's fourth largest city using CURES and NUDS. Between 2001 and 2004, diabetes prevalence increased from 5.4% to 6.6% in those aged 20–29 years, 19.7% to 25.2% in those aged 30–39 years, and 29.0% to 30.4% in those aged 40–49 years (8). The India State-Level Disease Burden Initiative Diabetes Collaborators also showed that the divergence between prevalence in 1990 and 2016 started in young adults, reaching statistical significance for men aged 50–54 years and women aged 55–59 years (2). These results suggest that the absolute burden of disease is potentially much higher (and increasing) in younger populations, attributable to the increased years of life lived with the disease, greater severity of complications, and premature death (4). Concerningly, the prevalence of diabetes in India is expected to rise further due to the high prevalence of prediabetes across the country, urbanization, and the epidemiological transition to more steeply rising prevalence among less affluent people and those in rural settings, where the majority of the Indian population reside with less access to health care (9). This will have long-lasting adverse effects on India's health and economy.

Of all deaths in India, deaths due to diabetes increased from an estimated 0.98% in 1990 to an estimated 3.1% in 2016, with an increase in both crude (131%) and age-standardized (64%) death rates (2,10). Evidence suggests that most adults with diabetes have at least one comorbid condition and an estimated 40% have three or more (11). This is a key trigger of disability, reduced quality of life, and premature death (12). In 2016, diabetes contributed to 2.2% of the total disability-adjusted life years in India, of which 57.2% was due to years of life lost (YLL) and 42.8% to years lived with disability (2). Diabetes-related premature deaths and comorbidities can impose a substantial economic burden by leading to reduced labor force participation and reduced productivity from work days lost to ill health (absenteeism) and decreased efficiency at work (presenteeism) (13). The resulting loss of productivity can impose a substantial economic burden on individuals, employers, and the government through reduced earnings, tax revenue, and gross domestic product (GDP) (14,15). In the United States, diabetes-related productivity loss was estimated to be U.S. dollars (USD) 90 billion in 2017, from a combination of loss of earnings, unemployment, and early death (14). In China, it was estimated that among the current population of working age with diabetes, USD 2.6 trillion in GDP would be lost to diabetes by the time they reached retirement age (16).

In India, the broader economic burden of diabetes has been less well studied. To date, most studies have focused on the direct costs of diabetes and its complications (17). Tharkar et al. (18) reported median annual indirect costs using the human capital approach of USD 103 for people with diabetes in 2010. A study by Sharma et al. (19) reported that the excess annual productivity costs due to diabetes ranged from USD 34 in government settings to USD 53 in private settings. Bommer et al. (20), who undertook a meta-analysis of the global economic burden of diabetes in adults aged 20 to 79 years, reported that the indirect costs associated with diabetes in India were 0.56% of GDP in 2015.

In the current study, we sought to estimate the impact of diabetes on productivity in India, both in terms of YLL and productivity-adjusted life years (PALYs) lost. The novelty of this work lies in the use of PALYs, a new measure to quantify productivity (16,21,22), which is conceptually similar to quality-adjusted life years. PALYs are estimated from years of life lived and a productivity index, which accounts for absenteeism and presenteeism, and adjusted for workforce participation.

RESEARCH DESIGN AND METHODS

Models

Life table models (23) were used to estimate the impact of diabetes on YLL and PALYs lost among the Indian population of working-age. Life tables were constructed using separate age- and sex-specific cohorts of the Indian population (in 5-year age groups) from 20 to 59 years of age with diabetes. These cohorts were followed until death or retirement age (60 years).

Numbers of deaths, cumulative years of life lived, and PALYs lived were estimated for those with diabetes by applying relevant age- and sex-specific mortality rates, labor force participation rates, and "productivity indices" (described below). The follow-up of the same cohort was resimulated, with the hypothetical assumption that they did not have diabetes. The differences between the two cohorts in terms of excess deaths, total YLL, and PALYs lost reflected the impact of diabetes. The World Health Organization standard 3% annual discount rate was applied to all years of life lived and PALYs lived beyond the first year (24).

Data Inputs

Population and Prevalence of Diabetes

Data regarding the prevalence of diabetes and population estimates for India, stratified by age and sex, were derived from the 2017 IDF Diabetes Atlas (25). Key data inputs are summarized in Supplementary Table 1.

Mortality Rates

Age- and sex-specific all-cause mortality data for India were derived from the 2017 Global Burden of Disease study (26). Death 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 CURES study of Asian Indian adults with and without diabetes (27). 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. These were then used to determine 5-year age-group and sex-specific RR parameters. Mortality rates, available for 5-year age bands, were extrapolated to age in single years using exponential functions. More details are provided in the Supplementary Material. Mortality rates by single year of age and diabetes status are summarized in Supplementary Table 2. 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 forecast (1% per year) (28). 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.

Labor Force Participation

Data on age- and sex-specific labor force participation in India were derived from the 2017 International Labor Organization estimates (29). In 2017, 78.7% of men and 23.8% of women contributed to the labor force. Labor force participation was lowest in those aged 20–24 years in both sexes (68.6% in men and 17.6% in women). Labor force participation was highest in those aged 35–39 years (98.9%) in men and 45–49 years (34.3%) in women.

Diabetes-related labor force dropouts were drawn from previously reported South Asian estimates, which ranged between 7.0% in those aged 20–40 years and 12.8% in those >40 years in women and 5.2% and 8.3% in men, respectively (20).

The labor force participation rates in those with diabetes were derived by applying relative reductions of diabetes-related labor force participation to the age- and sex-specific population labor force participation rates of India. The labor 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 labor force into full-time and part-time employment by disease status. In the model, years of life lived in the labor force were calculated as years of life lived by the cohort multiplied with the labor force participation rate. More details are available in the Supplementary Material.

Productivity Indices

Diabetes-related productivity loss was based on diabetes-related labor force dropouts and a productivity index, which characterizes the productivity of an individual in proportional terms, ranging from 1 (completely productive) to 0 (completely nonproductive) and captures productivity loss due to a disease or condition (16,21,22). The productivity index includes both absenteeism and presenteeism. Diabetes-related absenteeism and presenteeism estimates were obtained from a recent meta-analysis by Bommer et al. (20).

Absenteeism was estimated to be 7.5 days/year in both men and women (20), 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 (20). Available evidence did not support stratification of absenteeism and presenteeism estimates by age groups. We assumed a productivity index of 1.0 in people without diabetes. Hence, the overall diabetes-associated reduction in productivity due to absenteeism and presenteeism was assumed to be 3.8% in men (productivity index = 0.962) and 4.2% in women (productivity index = 0.958). The productivity impacts associated with diabetes were applied for the duration of the model time horizon and did not vary with age. To estimate PALYs lived by the diabetes cohort, productivity indices were multiplied by each year of life lived by the cohort in the labor force. The same method was used to estimate PALYs lived assuming diabetes did not exist (see the Supplementary Material for more details).

Cost of PALYs

Data on the GDP per person employed were derived from the 2019 Organization for Economic Co-operation and Development Compendium of Productivity Indicators (30). In India, in 2017, the GDP per person employed was USD 17,546 (Indian rupees [INR] 1,200,008 and purchasing power parity [PPP] 66,198, determined using the OECD exchange and PPP rates assuming USD constant prices in 2011) (30,31). We assumed that the economic value of each PALY was equivalent to the annual GDP per person employed in India (see the Supplementary Material for more details). An annual growth rate in GDP of 7.2% was applied for each year in the model (32).

Sensitivity and Scenario Analyses

One-way sensitivity analyses were performed to evaluate the impact of key input parameters on the model and the total PALYs lost attributable to diabetes and its associated economic impact. These inputs include: lower and upper uncertainty bounds (95% CI) around the RR of mortality associated with diabetes (27), lower and upper uncertainty bounds around the productivity indices based on enhancing and reducing absenteeism and presenteeism by 25%, and lower and upper uncertainty bounds surrounding the estimation of labor force dropouts based on a 25% variation.

Scenario analyses were performed to investigate other model assumptions. These include varying mortality risk, varying the annual GDP growth rate, and the annual discount rate. Firstly, the annual reduction in population mortality risk was doubled from the United Nations World Population Prospects rate of 1% per year to a 2% reduction per year and then by eliminating the temporal trend in mortality and maintaining the 2017 population mortality rates across the model time horizon. The annual GDP growth rate was doubled (to 14.4% per year), halved (to 3.6% per year), and assumed to not change over time. Finally, the annual discount rate was changed to 5% and 1.5%.

Data and Resource Availability

All data used in this study are included in this published article (and its Supplementary Material). The models generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

RESULTS

In 2017, the prevalence of diabetes was ~7.6% (8.0% in men and 7.1% in women) among the Indian population aged 20 to 59 years, equating to an estimated 54.4 million people (29.8 million men and 24.6 million women) (Supplementary Table 3).

Excess Deaths and YLL to Diabetes

Among Indians aged 20 to 59 years with diabetes followed up until retirement age (60 years), an estimated 8.5 million (62.7%) more deaths occurred in those with diabetes compared with the same cohort who were hypothetically assumed to not have diabetes. The excess deaths attributed to diabetes were higher in women (71.4%) compared with men (55.7%) (Table 1). However, total YLL was higher in men (7.7% of the total estimated years of life in the diabetes cohort) compared with women (7.0%). It was estimated that the current cohort with diabetes would lose 42.7 million years (7.4%) when followed up until retirement age. This equated to an average of 0.8 YLL per person with diabetes (0.9 in men and 0.7 in women).

PALYs Lost to Diabetes

The estimated PALYs lived by the current cohort of Indian people of working-age living with diabetes are summarized in Table 2. Overall, it was estimated that diabetes reduced PALYs lived by 89.0 million (23.3% of the total estimated PALYs in the diabetes cohort), 56.6 million (18.5%) in men and 32.4 million (42.5%) in women. This equated to an average of 1.6 PALYs lost per person with diabetes over their working lifetime.

Assuming a constant GDP per full-time employee of INR 1,200,008 (USD 17,547; PPP 66,198), the total productivity loss attributable to diabetes would be associated with an estimated INR 176.6 trillion loss (USD 2.6 trillion; PPP 9.8 trillion) in GDP. This is equivalent to an average GDP loss of INR ~3,249,075 (USD 47,508; PPP 179,234) per person with diabetes.

Sensitivity and Scenario Analyses

The major contributors to productivity loss were labor force participation (51.3%) and premature death (33.3%), followed by absenteeism (12.3%) and presenteeism (3.1%) (Fig. 1). In men, diabetes-related premature deaths (42.3% vs. 18.0%) and absenteeism (14.8% vs. 7.9%) were the major contributors to productivity loss compared with women, while the proportion of PALYs lost to labor force participation was higher in women (70.4%) than men (40.0%). The proportion of PALYs lost to presenteeism was similar in both sexes. The majority of costs associated with productivity losses were caused by diabetes-related labor force dropouts (INR 88.1 trillion; USD 1.3 trillion; PPP 4.9 trillion) and premature deaths (INR 57.1 trillion; USD 836.0 billion; PPP 3.2 trillion), followed by absenteeism (INR 21 trillion; USD 308.2 billion; PPP 1.2 trillion) and presenteeism (INR 5.4 trillion; USD 78.8 billion; PPP 0.3 trillion).

The model was sensitive to several data inputs, including diabetes-related labor force dropouts, productivity indices, the increased risk of mortality associated with diabetes, the annual discount rate, and temporal trend in population mortality risk (Fig. 2 and Supplementary Table 4). Compared with the base case, when the lower and upper uncertainty bounds (25% variation) around absenteeism and presenteeism estimates were applied, the total PALYs lost to diabetes were increased by 3.4% and reduced by 3.2%, respectively; when the lower and upper uncertainty bounds (25% variation) around labor force dropouts were applied, the total PALYs lost to diabetes were increased and reduced by 13.2%,

Table 1—Deaths and years of life lived in people with diabetes assuming diabetes did not exist, and excess deaths and YLL attributable to diabetes over the working lifetime of the Indian working-age population, simulated from life table modeling

Age group (years)	Deaths in diabetes cohort	Deaths in "diabetes cohort" assuming no diabetes	Excess deaths in diabetes cohort* (%)	Years of life lived in diabetes cohort	Years of life lived in "diabetes cohort" assuming no diabetes	YLL** (%)
Men						
20–24	184,499	70,453	114,045 (61.8)	10,064,822	11,198,343	1,133,522 (10.1)
25–29	402,550	160,509	242,040 (60.1)	21,085,826	23,317,513	2,231,688 (9.6)
30–34	758,272	313,934	444,338 (58.6)	37,507,249	41,292,702	3,785,452 (9.2)
35–39	1,164,691	498,720	665,971 (57.2)	53,624,029	58,779,109	5,155,080 (8.8)
40–44	1,483,307	655,092	828,215 (55.8)	62,889,005	68,490,747	5,601,742 (8.2)
45–49	1,555,639	706,574	849,065 (54.6)	60,214,266	64,887,565	4,673,299 (7.2)
50–54	1,319,123	616,237	702,886 (53.3)	44,420,715	47,125,235	2,704,520 (5.7)
55–59	639,730	303,335	336,395 (52.6)	20,281,493	20,920,003	638,510 (3.1)
Total	7,507,810	3,324,855	4,182,955 (55.7)	310,087,404	336,011,217	25,923,813 (7.7)
Women						
20–24	241,879	61,138	180,741 (74.7)	12,411,812	13,819,921	1,408,109 (10.2)
25–29	429,059	113,604	315,454 (73.5)	20,816,665	23,004,352	2,187,687 (9.5)
30–34	691,734	190,535	501,199 (72.5)	30,847,921	33,918,505	3,070,584 (9.1)
35–39	952,693	271,785	680,908 (71.5)	37,890,118	41,462,516	3,572,398 (8.6)
40–44	1,141,962	336,221	805,741 (70.6)	38,805,974	42,213,127	3,407,153 (8.1)
45–49	1,177,396	356,327	821,070 (69.7)	31,282,166	33,840,015	2,557,849 (7.6)
50–54	979,825	281,480	698,345 (71.3)	35,041,089	35,073,084	31,995 (0.1)
55–59	411,824	113,588	298,237 (72.4)	17,699,616	18,257,455	557,840 (3.1)
Total	6,026,372	1,724,677	4,301,695 (71.4)	224,795,362	241,588,976	16,793,614 (7.0)
Total	13,534,182	5,049,532	8,484,650 (62.7)	534,882,766	577,600,193	42,717,427 (7.4)

The percentages represent the excess deaths as a proportion of the total estimated deaths in the diabetes cohort and the YLL as a proportion of the total years of life lived in the diabetes cohort. *Excess deaths represent all-cause deaths observed in those with diabetes compared with the same cohort assuming hypothetically they did not have diabetes. **Calculation of YLL was subject to an annual discount rate of 3%. Deaths and years of life lived were calculated from population and mortality data but, due to rounding of numbers for each age group presented in this table, total values may not precisely match.

Table 2—PALYs lived in people with diabetes assuming diabetes did not exist, and the PALYs lost attributable to diabetes over the working lifetime of the Indian working-age population, simulated from life table modeling

Age group (years)	PALYs lived in diabetes cohort	PALYs lived in "diabetes cohort" assuming no diabetes	PALYs lost* (%)	PALYs lost per person with diabetes
Men				
20–24	8,376,128	10,394,243	2,018,115 (19.4)	4.1
25–29	17,945,058	22,150,739	4,205,681 (19.0)	3.8
30–34	32,043,483	39,473,691	7,430,208 (18.8)	3.4
35–39	45,209,717	55,675,600	10,465,883 (18.8)	3.0
40–44	51,590,452	63,467,448	11,876,996 (18.7)	2.4
45–49	47,245,144	57,937,535	10,692,391 (18.5)	1.8
50–54	32,784,833	39,951,574	7,166,741 (17.9)	1.2
55–59	13,843,951	16,590,168	2,746,217 (16.6)	0.5
Total	249,038,766	305,640,998	56,602,232 (18.5)	1.9
Women				
20–24	2,253,619	3,865,520	1,611,901 (41.7)	2.5
25–29	4,199,935	7,074,414	2,874,479 (40.6)	2.4
30–34	6,551,927	11,018,148	4,466,221 (40.5)	2.2
35–39	8,108,852	13,774,269	5,665,417 (41.1)	1.9
40–44	8,024,506	13,925,675	5,901,169 (42.4)	1.6
45–49	5,931,054	10,726,066	4,795,012 (44.7)	1.1
50–54	5,546,913	10,187,012	4,640,100 (45.5)	1.0
55–59	3,194,343	5,687,020	2,492,677 (43.8)	0.5
Total	43,811,148	76,258,123	32,446,975 (42.5)	1.3
Total	292,849,914	381,899,121	89,049,206 (23.3)	1.6

The percentages represent the PALYs lost as a proportion of the total estimated PALYs in the diabetes cohort. *Calculation of PALYs was subject to an annual discount rate of 3%. PALYs lived were calculated from years of life lived and productivity indices were adjusted for labor force participation but, because of rounding of numbers for each age-group presented in this table, total values may not precisely match.

respectively; and applying the lower and upper uncertainties bounds of the 95% CI around the increased risk in all-cause mortality associated with diabetes, PALYs lost were decreased by 14.4% and increased by 12.0%, respectively.

In scenario analyses, the PALYs lost increased by 1.2% when temporal trends in population mortality risk were removed, whereas PALYs lost decreased by 1.1% when the annual reduction in population mortality risk was doubled to 2% per year. Doubling the annual GDP growth rate to 14.4% resulted in an increase in the estimate of GDP lost to INR 246.2 trillion (USD 3.6 trillion; PPP 13.6 trillion), and reducing the annual GDP growth rate to half (3.6%) resulted in a decrease in the estimate of GDP lost to INR 141.8 trillion (USD 2.1 trillion; PPP 7.8 trillion), while removing all temporal trends in GDP decreased the estimate of GDP lost further to INR 107 trillion (USD 1.6 trillion; PPP 6 trillion). Finally, reducing the annual discount rate to 1.5% resulted in a 14.8% increase in PALYs lost and increasing the annual discount rate to 5% led to a 15.1% reduction in PALYs lost (Fig. 2 and Supplementary Table 4).

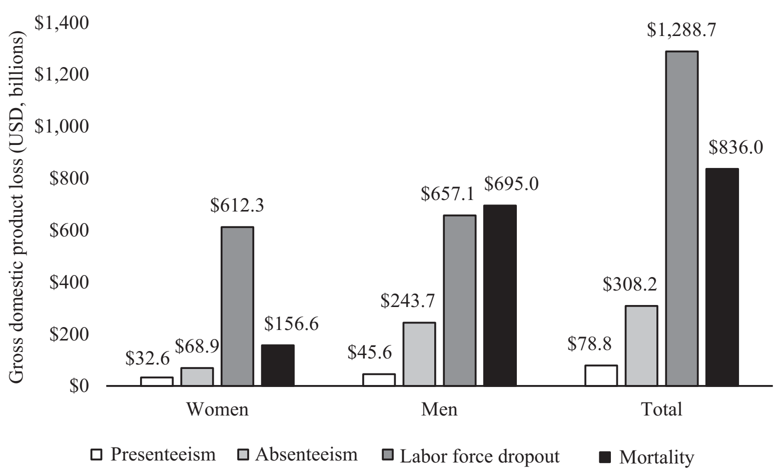

Figure 1—Economic burden of productivity loss attributable to diabetes due to diabetes-related premature deaths, labor force dropouts, absenteeism, and presenteeism over the working lifetime of the current Indian working-age population. Due to rounding of numbers for men and women presented in this figure, total values may not precisely match.

CONCLUSIONS

The results of our modeling study highlight the substantial impact of diabetes on years of life lived, productivity, and its associated economic impact in India. Among the current Indian population of working age (20–59 years) with diabetes followed up until retirement (60 years), diabetes was predicted to cause 8.5 million excess deaths, 42.7 million YLL, and 89 million PALYs lost, equating to INR 176.6 trillion (USD 2.6 trillion; PPP 9.8 trillion) in lost GDP.

Productivity loss arose from a combination of premature death, diabetes-associated labor force dropouts, absenteeism, and presenteeism. The excess deaths attributed to diabetes were

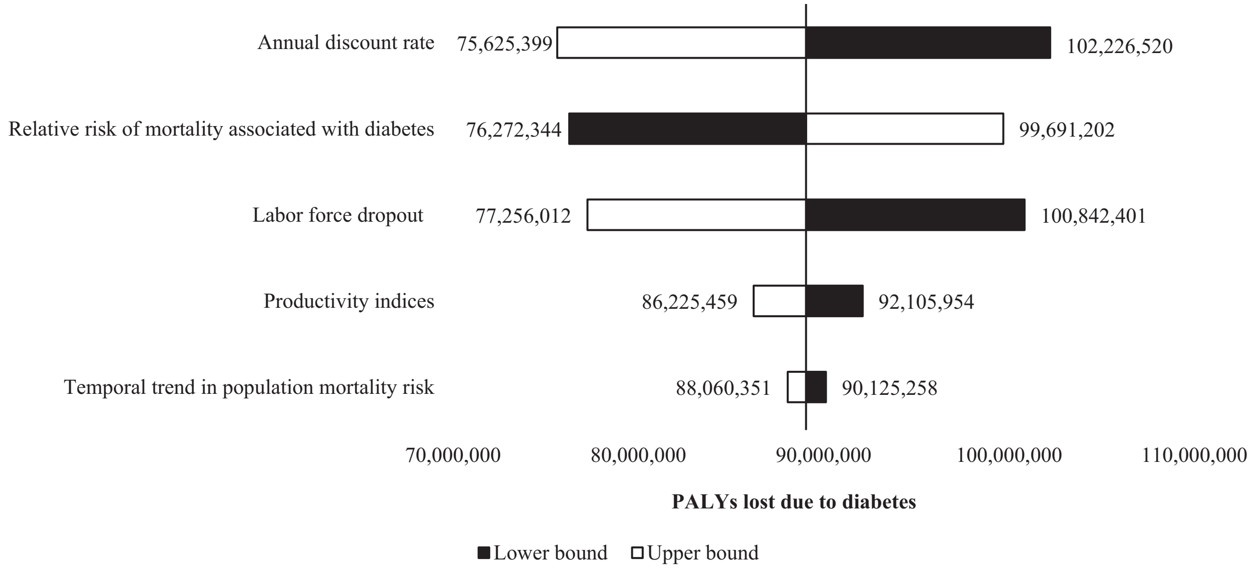

Figure 2—Tornado diagram demonstrating the impact of variations in input parameters on total PALYs lost attributable to diabetes. The following variations were applied to the input parameters: *1*) annual discount rate: 1.5% to 5%; *2*) RR of mortality associated with diabetes: 95% CI; *3*) labor force dropout: 25% variation; *4*) productivity indices: 25% variation was applied to absenteeism and presenteeism estimates; and *5*) temporal trend in population mortality risk: 0% to 2% per year.

higher in women (relative change of 71.4% in total deaths in the diabetes cohort compared with the same cohort who were assumed to hypothetically not have diabetes) compared with men (55.7%). This is consistent with previous studies showing that the RR of all-cause mortality in women with diabetes (compared with women without diabetes) is 13.0% greater than the RR of all-cause mortality in men with diabetes (33). Furthermore, the prevalence of diabetes and YLL to diabetes were considerably higher among men compared with women. Our study showed that men with diabetes were predicted to have a relative reduction of 7.7% of their total estimated years of life lived compared with the same cohort who were hypothetically assumed to not have diabetes, while women were predicted to lose 7.0%. An earlier Australian burden of disease study supports this finding, in which men with diabetes were projected to experience greater YLL (2.2% of total YLL) compared with women with diabetes (2.1%) (34). The relative impact of diabetes on YLL was higher among the younger population, despite the lower prevalence of diabetes in that age group. For example, there was a relative reduction of ∼10.1% of years of life lived attributable to diabetes in men and women aged 20–24 years compared with ∼7.4% and 3.1% in men and women aged 45–49 and 55–59 years, respectively. This is consistent with studies showing that diabetes in younger age populations exerts a greater impact compared with older age populations: attributable to high premature mortality risk, the increased years of life lived with the disease and greater severity of complications among younger age groups (35).

Our study estimated a 23.3% relative reduction in the total number of PALYs (discounted) lived or 1.6 PALYs (discounted) lost per person attributable to diabetes in the working-age Indian population, followed over their working lifetime. Without discounting, 2.2 PALYs were lost per person with diabetes, which is considerably higher than a similar study in Australia, where the total number of PALYs were reduced by 11.1% or 1.4 PALYs (undiscounted) were lost per person with diabetes over their working lifetime (21). The difference in total PALYs lost is likely a result of the prevalence of diabetes in India being almost double that of Australia among the working-age population. The difference in PALYs lost per person is likely a result of the earlier onset of diabetes and lower retirement age in India and the inclusion of labor force participation in our study (which was not included in the Australian study). In India, the retirement age is ∼10 years lower than in Australia. Therefore, people living with diabetes in India experienced higher productivity losses over a shorter time frame. A similar study in China, where retirement age and prevalence of diabetes is similar to India, attributed a 15.1% reduction in total PALYs (discounted by 3% per annum) or 1.3 PALYs (discounted) lost per person to diabetes (16). The findings of our study suggest that the impact of diabetes on productivity loss is markedly higher in India compared with other Asian developing countries and a substantial economic burden, with an estimated GDP loss of INR 176.6 trillion (USD 2.6 trillion; PPP 9.8 trillion). We estimated INR 7.4 trillion (USD 108 billion; PPP 409 billion) in lost GDP in 2017. This is far greater than the estimated USD 1.96 billion in lost productivity costs due to cardiovascular disease in India in 2015 (36), highlighting the substantial economic burden of diabetes. Our estimations are conservative, as our model did not consider the direct costs of diabetes, including costs of diagnosis, treatment, and care. This is supported by a recent study that showed that diabetes-related productivity losses accounted for 27.5% of the total economic burden in the United States in 2017 and 34.7% of the total economic burden globally in 2015 (14,20). In fact, Bommer et al. (20) suggested that diabetes-related productivity losses accounted for 56.0% of the total economic burden attributable to diabetes in India.

In our model, the absolute number of PALYs lost over the working lifetime was greater in men than women (56,602,232 and 32,446,975, respectively). This is due to the higher prevalence of diabetes in men than in women. However, the relative reduction in productivity was higher in women with diabetes (42.5% relative reduction in PALYs in the diabetes cohort compared with the same cohort who were hypothetically assumed not to have diabetes) compared with men with diabetes (18.5%). Women with diabetes experienced a higher proportion of productivity losses owing to labor force participation dropouts (70.4% of total productivity loss vs. 40.0%) and presenteeism (3.7% vs. 2.8%) compared with men with diabetes. This is consistent with a U.S. study that demonstrated that women with diabetes experienced almost double the labor force participation dropouts and absenteeism compared with men with diabetes (37). There is an abundance of evidence that supports the reductions in labor force participation in both men and women with diabetes compared with those without diabetes (37–39). Reductions in labor force participation may be influenced by duration and severity of diabetes and are likely the result of diabetes-related complications (39).

Our modeling study estimated an average GDP loss of INR 3,934,507 (USD 57,531; PPP 217,045) per person with diabetes over their working lifetime in India. The Indian Diabetes Prevention Program reported the cost to prevent one case of diabetes with three interventions: lifestyle modification, INR 47,341 (USD 1,052); metformin, INR 49,280 (USD 1,095); and lifestyle modification and metformin, INR 61,133 (USD 1,359) (40). These amounts are marginal compared with the estimated GDP lost due to productivity losses. Hence, this amount could be potentially spent on strategies for diabetes prevention, treatment, and control and should be considered as a potential long-term investment. However, further research is needed to economically evaluate the cost-effectiveness of implementing such prevention/intervention strategies.

The main strength of our study was the use of the productivity measure, the PALY, which allows productivity to be estimated at a population level, and for a financial value to be ascribed to quantify the broader economic implications (missed production opportunities) (22). In this study, we used GDP per employee to reflect the economic cost of each PALY. GDP is the most regularly used measure of a country's economic well-being (41) and provides an economic snapshot of the country. Another strength of the study was the use of contemporary age- and sex-specific estimates of diabetes prevalence, mortality risk, and labor force participation. In this study, the major contributors to diabetes-related productivity losses were labor force dropouts (51.3%) and premature mortality (33.3%). Increased spending on research and health care to reduce diabetes-related morbidity and mortality may reduce the broader economic implications associated with productivity loss.

Our study has several limitations that warrant mention. Population labor force participation rates in women were low (24%), which may be due to their increased participation in unpaid work such as carer duties. Nevertheless, due to a lack of data on participation in unpaid work and the impact that diabetes may have on this, we were unable to model the productivity impacts beyond employed persons. Data on absenteeism and presenteeism in India were available; however, there was high risk of bias with presenteeism data, with 0.06, −0.10, and −0.31 more work days lost per year in people with diabetes compared with people without diabetes in private clinic, government, and rural settings, respectively (20). Data on labor force participation in people with diabetes in India were not available. Therefore, we used estimates from a meta-analysis of multiple countries from South Asia with regards to absenteeism, presenteeism, and labor force dropouts, which may not have been applicable to the Indian population. In addition, we did not have data on how diabetes-related productivity (in terms of absenteeism, presenteeism, and labor force dropouts) varied with duration of diabetes, treatment control, or comorbidities, and therefore, the productivity impacts for people with diabetes remained constant over the model time horizon and did not vary with age. However, we performed sensitivity analyses to explore the uncertainty around productivity indices. The model was less sensitive toward the lower and upper uncertainty bounds around absenteeism and presenteeism, where PALYs lost to diabetes were increased by 3.4% and reduced by 3.2%, respectively, although the model was more sensitive to variations in labor force dropouts (±13.2%). Another potential issue was that we used the current cohort of Indian people with diabetes and followed them until retirement age. However, we did not consider the prediabetic population as well as incident cases of diabetes. The ICMR-INDIAB study estimated that the prevalence of prediabetes in 15 states in India in people aged ≥20 years was 10.3%, which was far greater than the estimated prevalence of diabetes of 7.3%, implying that there is a large number of people who may develop diabetes in the future (9). Thus, these results may be considered an underestimation of the true effect of diabetes on work productivity. We acknowledge that our results did not consider the impact of the coronavirus disease 2019 (COVID-19) pandemic on our findings. Singh et al. (42) showed that during the COVID-19 lockdowns in India, there were difficulties in accessing health care and medicines, as well as income and job losses. Difficulties in accessing medicines and job loss were associated with worsening of diabetes and hypertension symptoms (42). Theoretically, worsening of diabetes will increase productivity losses, but the impact of the COVID-19 pandemic on the wider community (in terms of access to health care, productivity, employment, and mortality) must also be considered.

While life table modeling is a well-recognized epidemiological tool, modeling analyses of any kind are subject to uncertainties. The following sources of uncertainties warrant mention: *1*) We assumed that current projections of temporal trends for the population mortality risk and GDP growth held true across the model time horizon. However, our scenario analyses demonstrate that the model was sensitive to changes in the population mortality risk and GDP trends. *2*) The contribution of comorbidities (obesity and cardiovascular disease) and complications of diabetes (kidney disease and hypoglycemia) to productivity loss could not be distinguished. *3*) In this study, due to lack of evidence, all employees were assumed to work full-time. Therefore, the impact of diabetes upon unpaid and part-time work was not included. Despite these limitations, the overall conclusion of our study is unlikely to have changed.

Conclusion

Prevalence of diabetes in younger age populations is drastically rising in India, which has long-term health and productivity impacts. Quantifying the economic burden of diabetes in terms of productivity loss is a vital measure to capture the broader economic burden (beyond direct health care costs). Our study highlights the substantial productivity losses attributable to diabetes in the current working-age population living with diabetes in India. The impact of diabetes on productivity loss has potential economic implications. Interventions aimed at the prevention, treatment, and management of diabetes should be considered a worthwhile investment. Nevertheless, to determine which interventions provide the best value for money, cost-effectiveness studies of feasible diabetes prevention and control programs in India are needed.

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