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Article

Macroeconomic Consequences of Type 1 Diabetes: Productivity Loss and Healthcare Expenditure

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Abstract

Individuals with T1D carry the economic burden of the illness itself as well as its treatment, along with the burden on healthcare systems and the economy. In this study, we consider the macroeconomic consequences of T1D in India in terms of productivity loss and healthcare expenditure. In order to quantify these direct and indirect costs of T1, we use data from global and national health surveys, economic studies, and healthcare databases to analyse trends from 2000 to 2045. We found that T1D is becoming increasingly common and that the number of affected people is predicted to exceed 124.9 million by 2045 and that these costs will be substantial for healthcare and productivity. The economic impact is estimated to increase directly to USD 8.5 billion in 2021 while incrementally increasing to USD 12.8 billion by 2045, while the indirect costs that include absenteeism, presenteeism, and mortality before active age contribute to magnifying. Complications like neuropathy, retinopathy, and coronary artery disease also play a major role in the disease burden. The study stresses the constraints of macroeconomic consequences of T1D in India through improved access to insulin and early diagnosis and workplace accommodations. This increasing public health challenge requires policymakers to enforce cost-effective strategies to tackle this challenge and to minimise the economic burden on the individuals and on the healthcare system.

Keywords: Type 1 diabetes, healthcare expenditure, productivity loss, economic burden, India, diabetes complications.

INTRODUCTION

Type 1 diabetes (T1D) is a chronic autoimmune condition that requires lifelong insulin therapy and rigorous management, posing significant challenges to individuals, healthcare systems, and economies worldwide (Magliano et al., 2021; Roglic, 2016). Unlike type 2 diabetes, which is often linked to lifestyle factors, T1D primarily affects children and young adults, leading to long-term productivity loss and substantial healthcare expenditure (Bommer et al., 2017; Seuring et al., 2015). In India, the prevalence of T1D is rising, with an estimated 229,400 children and adolescents living with the condition in 2021, and this number is expected to grow significantly in the coming decades. The economic burden of T1D is multifaceted, encompassing direct costs such as insulin, medical care, and hospitalizations, as well as indirect costs due to absenteeism, presenteeism, and premature mortality (Lee & Callaghan, 2020; Mohan et al., 2007). Globally, the macroeconomic consequences of T1D are profound. The condition not only strains healthcare systems but also reduces workforce productivity, particularly in low- and middle-income countries like India, where access to affordable insulin and advanced care remains limited (Ramachandran et al., 2009). In 2019, the global economic burden of diabetes, including T1D, was estimated at $1.3 trillion, with indirect costs accounting for a significant portion of this burden (Bommer et al., 2017). In India, the direct healthcare expenditure for diabetes reached $8.5 billion in 2021, with T1D contributing a substantial share due to the high cost of insulin and lifelong management. Furthermore, the indirect costs of T1D, such as productivity loss and premature mortality, are often underestimated, highlighting the need for comprehensive economic assessments (Seuring et al., 2015).

Despite the growing prevalence of T1D, few studies have specifically evaluated its macroeconomic consequences, particularly in developing countries like India. Existing research has primarily focused on type 2 diabetes, leaving a critical gap in understanding the unique challenges posed by T1D (Mohan et al., 2007; Anjana et al., 2017). This paper aims to address this gap by examining the macroeconomic consequences of T1D in India, with a focus on productivity loss and healthcare expenditure. By analysing trends from 2000 to 2045, this study highlights the escalating economic burden of T1D and underscores the need for targeted interventions to mitigate its impact on individuals and economies.

OBJECTIVES OF THE STUDY

1. To quantify the direct healthcare expenditure associated with type 1 diabetes (T1D) in India.
2. To assess the indirect economic costs of T1D, particularly productivity loss.
3. To Propose Policy Recommendations for Mitigating the Economic Burden of T1D.

METHODOLOGY

This study analyses macroeconomic implications of Type 1 Diabetes (T1D) in India with respect to healthcare expenditure and productivity loss using the IDF Diabetes Atlas (International Diabetes Federation), government reports (National Health Mission, NITI Aayog) and peer-reviewed studies. Direct costs (insulin, hospitalisation), indirect costs (absenteeism, premature mortality), and policy interventions and systemic gaps are evaluated in quantitative methods using the Human Capital Approach and Friction Cost Method; qualitative analysis of the systemic gaps. Our study seeks to quantify, first, India's T1D healthcare spending; second, the feasibility of productivity loss; and third, proposals for policy solutions (e.g., insulin subsidies, telemedicine). The limits are the fact that the global estimates are used, and there is a disparity between regions. It also requires only aggregated, cited data to be used.

LITERATURE REVIEW

Type 1 diabetes (T1D) is an expensive disease to bear, both financially and economically, and to the health of iType 1 diabetes (T1D) imposes a substantial economic burden on individuals and healthcare systems worldwide (Butt et al., 2024), encompassing direct healthcare costs and indirect productivity losses. This review synthesises existing literature on the financial impact of T1D, analysing healthcare expenditures, productivity losses, and policy interventions aimed at mitigating these costs. T1D imposes a significant macroeconomic burden through both direct healthcare costs and indirect productivity losses, with financial implications including insulin therapy, continuous glucose monitoring, hospitalisations, and routine care (Bommer et al., 2017; Parker et al., 2023). The economic strain is exacerbated by disparities in healthcare access, particularly in low- and middle-income countries where insulin and advanced care remain limited (Zhou et al., 2016; Hex et al., 2012). Productivity losses stem from absenteeism, presenteeism, and early retirement due to complications like neuropathy and cardiovascular disease (Khunti et al., 2016; Seuring et al., 2015), while employment discrimination further reduces earning potential (Tao et al., 2010). Global diabetes-related healthcare costs exceeded $966 billion in 2021, with a substantial proportion linked to preventable complications, prompting calls for cost-effective interventions such as subsidised care, digital health technologies, and preventive measures (Basu et al., 2021; Yoshioka et al., 2004). Addressing these challenges requires strategic investments in research, equitable access, and policy reforms to mitigate long-term economic impacts (Bommer et al., 2018; Parker et al., 2023; Das et al., 2022).

T1D imposes a growing economic burden in India and South Asia, where healthcare systems struggle with limited access to insulin, high out-of-pocket expenditures, and inadequate diabetes care infrastructure (Cefalu et al., 2018). Unlike high-income countries, where universal healthcare may offset costs, South Asian patients often face catastrophic health spending, with insulin and glucose monitoring devices consuming a significant portion of household income (Nanda & Sharma, 2023). Studies estimate that only 3% of Indian children with T1D achieve optimal glycaemic control, leading to frequent complications and hospitalisations, further straining underfunded public health systems (McClintock et al., 2021). The indirect economic burden is equally severe, with school dropouts, job losses, and early mortality disproportionately affecting low-income families (Paul et al., 2021). Additionally, cultural stigma and lack of awareness exacerbate poor disease management, increasing long-term costs (Gujral et al., 2019). Government initiatives like India's National Diabetes Control Program remain underfunded, while insulin pricing disparities persist due to reliance on imported analogues (Kumar, 2013). Digital health interventions, such as mHealth-based glucose monitoring, show promise in improving

adherence at lower costs, but scalability remains a challenge in rural areas (Kaufman & Khurana, 2016). Without urgent policy reforms—including price regulation, local insulin production, and expanded diabetes education programs—the economic toll of T1D in South Asia will continue to rise, worsening health inequities (Walker et al., 2023) .

Tables (1) Diabetes in India (2000–2045)

DIABETES ESTIMATES (20-79 YEARS)					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
People with diabetes, in 1,000s	32,674.4	61,258.4	74,194.7	92,973.7	124,874.7
Age-adjusted comparative prevalence of diabetes, %	-	9.0	9.6	10.4	10.8
People with undiagnosed diabetes, in 1,000s	-	-	39,397.4	-	-
Proportion of people with undiagnosed diabetes, %	-	-	53.1	-	-

The global diabetes burden among adults (20–79 years) has surged from 32.7 million cases in 2000 to 74.2 million in 2021, with projections hitting 124.9 million by 2045. Age-adjusted prevalence rose from 9.0% (2011) to 9.6% (2021) and is expected to reach 10.8% by 2045. Alarmingly, 53.1% of cases (39.4 million) remained undiagnosed in 2021, signalling critical gaps in healthcare access and screening. Without urgent action—including better diagnostics, prevention, and awareness—this escalating crisis will lead to higher complications and costs. Public health strategies must prioritise early detection and management to curb the growing epidemic.

IMPAIRED GLUCOSE TOLERANCE (IGT) ESTIMATES					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
People with IGT, in 1,000s	-	20,467.5	40,143.8	50,045.4	65,557.3
Age-adjusted comparative prevalence of IGT, %	-	3.0	5.4	5.6	5.8

IGT cases surged from 20.5 million (2011) to 40.1 million (2021), with projections hitting 65.6 million by 2045. Age-adjusted prevalence doubled from 3.0% (2011) to 5.4% (2021), rising further to 5.8% by 2045. This growing prediabetic population underscores urgent needs for lifestyle interventions to prevent progression to diabetes.

IMPAIRED FASTING GLUCOSE (IFG) ESTIMATES					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
People with IFG, in 1,000s	-	-	75,123.9	85,065.3	95,598.7
Age-adjusted comparative prevalence of IFG, %	-	-	7.8	8.2	8.3

IFG cases reached **75.1 million in 2021**, projected to rise to **95.6 million by 2045**. Age-adjusted prevalence increased from **7.8% (2021) to 8.3% (2045)**, signalling a growing prediabetes crisis. Early lifestyle and dietary interventions are critical to curb diabetes risk.

MORTALITY ATTRIBUTABLE TO DIABETES					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
Deaths attributable to diabetes	-	983,203.0	647,831.0	-	-
Proportion of diabetes-related deaths under 60 y, %	-	-	2.8	-	-

Deaths fell sharply from **983,203 (2011) to 647,831 (2021)**, suggesting improved care. However, **2.8% of deaths occurred under age 60**, highlighting risks for younger adults. Urgent action is needed to prevent early mortality through better management and awareness.

TYPE 1 DIABETES ESTIMATES					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
New cases of type 1 diabetes (0-14 y), in 1,000s	18.1	-	19.2	-	-
New cases of type 1 diabetes (0-19 y), in 1,000s	-	-	24.0	-	-
Type 1 diabetes (0-14 y), in 1,000s	66.9	-	124.6	-	-
Type 1 diabetes (0-19 y), in 1,000s	-	-	229.4	-	-

New cases in children (0–14 years) rose from **18,100 (2000) to 19,200 (2021)**, while total cases in this age group nearly doubled from **66,900 to 124,600**. Among youth (0–19 years), **24,000 new cases** and **229,400 total cases** were reported in 2021, reflecting growing prevalence. Early diagnosis and management remain critical to address this rising burden.

HYPERGLYCEMIA IN PREGNANCY (HIP)					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
Live births affected by HIP	-	-	6,182,373.9	-	-
Prevalence of gestational diabetes mellitus (GDM), %	-	-	29.3	-	-
Live births affected by other types of diabetes	-	-	220,541.9	-	-
Live births affected by diabetes detected prior to pregnancy	-	-	194,791.2	-	-

In 2021, an alarming 6.2 million live births were affected by HIP, with 29.3% attributed to gestational diabetes (GDM). Additionally, 220,500 births involved other diabetes types, while 194,800 had pre-existing diabetes. These figures underscore HIP's growing impact, demanding better maternal screening and care to safeguard maternal and child health.

DIABETES-RELATED HEALTH EXPENDITURE					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
Total diabetes-related health expenditure, USD million	-	-	8,485.8	10,305.5	12,834.3
Total diabetes-related health expenditure, ID million	-	-	32,054.9	38,928.6	48,481.1
Diabetes-related health expenditure per person, USD	-	68.0	114.4	138.9	173.0
Diabetes-related health expenditure per person, ID	-	-	432.0	524.7	653.4

Global diabetes-related health expenditure surged from 8.5 billion **(2021) to a *projected* 12.8 billion by 2045** (USD). Per-person costs jumped from **68 (2011) *to* 114 (2021)**, expected to hit **$173 by 2045**. In ID terms, spending grew from **32.1 billion (2021)** to a projected **48.5 billion (2045)**, reflecting the escalating financial burden on healthcare systems. Prioritising cost-effective prevention is critical.

DEMOGRAPHICS					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
Total adult population (20-79 y), in 1,000s	567,714.0	737,003.3	893,910.0	1,022,119.2	1,154,012.2
Population of children (0-14 y), in 1,000s	361,182.0	-	359,208.6	-	-
Population of children and adolescents (0-19 y), in 1,000s	-	-	485,464.9	-	-

Adult (20–79y) numbers surged from **568M (2000) to 894M (2021)**, projected to hit **1.15B by 2045**. Children (0–14y) held steady near **359M (2021)**, while youth (0–19y) totalled **485M**. Ageing populations amplify diabetes risks, demanding targeted healthcare strategies.

COMPLICATIONS OF DIABETES				
Microvascular	Nephropathy:	5.9%	Retinopathy:	0.8%
	Neuropathy:	10.6%		
Macrovascular	Coronary artery disease:	2.5%	Cerebrovascular disease:	0.3%
	Peripheral artery disease:	0.0%	Heart failure:	0.2%

Diabetes causes severe complications : **neuropathy (10.6%), nephropathy (5.9%), retinopathy (0.8%)**, and **coronary disease (2.5%)**. Early detection and management are crucial to prevent irreversible damage to nerves, kidneys, eyes, and heart. Proactive care reduces risks and improves long-term health outcomes for patients.

GLOBAL DIABETES-RELATED HEALTH EXPENDITURE					
Indicator	**2000**	**2011**	**2021**	**2030**	**2045**
Total diabetes-related health expenditure, USD million	-	465,000.0	966,000.0	1,027,600.0	1,053,700.0
Total diabetes-related health expenditure, ID million	-	499,000.0	1,421,852.0	1,549,800.0	1,630,100.0
Diabetes-related health expenditure per person, USD	-	1,274.0	1,838.4	-	-
Diabetes-related health expenditure per person, ID	-	1,366.0	2,706.7	-	-

Source : *International Diabetes Federation*

Diabetes-related health costs skyrocketed from 465 billion (2011) to 966 billion (2021), projected to hit 1.05 trillion by 2045 (USD). In ID terms, spending's jumped from 499 billion to 1.42 trillion (2021) nearly 1.64 trillion by 2045. Per-person costs doubled from 1,274 (2011) to 1,838 (2021) USD, highlighting unsustainable growth. Urgent cost-control measures and prevention strategies are needed to curb this financial crisis.

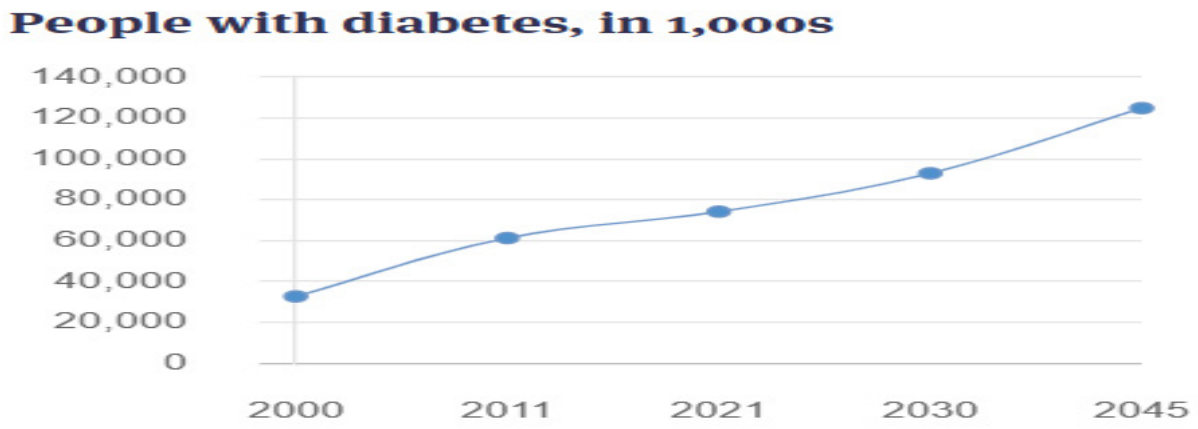

Figure 1: *Total Number of People with Diabetes*

"The study reveals several critical findings regarding the diabetes epidemic in India. First, the prevalence of diabetes has risen dramatically, with the number of people affected increasing from **32.7 million in 2000 to 74.2 million in 2021**, and projections indicating a further rise to **124.9 million by 2045**. The age-adjusted comparative prevalence of diabetes has also climbed, from **9.0% in 2011 to 9.6% in 2021**, with an expected increase to **10.8% by 2045**. Second, a significant portion of the population remains undiagnosed, with **53.1% of people with diabetes unaware of their condition in 2021**, underscoring gaps in screening and awareness programs." Third, diabetes leads to an enormous cost to the US per person (USD 173.0 in 2045), per household (USD 1,800 in 2045), and nationwide (USD 12.8 billion in 2045). Although education and screening within primary care have reduced disparities in diabetes population estimates, final costs associated with diabetes are driven primarily by complications ' beyond microvascular problems like neuropathy and retinopathy and macrovascular diseases such as coronary disease ' which impose an enormous health care burden on systems of care and deteriorate quality of life for those affected. Given the prevalence of these findings in India, what is

needed are comprehensive diabetes interventions.

Table 2: *Descriptive Analysis of Global Diabetes Data (2000–2045)*

Category	Key Trend	Statistical Insight	Implication
Diabetes Prevalence	Rapid increase in cases	**281% rise** (2000: 32.7M → 2045: 124.9M)	Growing healthcare burden; urgent prevention needed.
Undiagnosed Diabetes	Over half of cases undetected (2021)	53.1% (39.4M) undiagnosed	Critical gaps in screening/awareness programs.
Prediabetes (IGT/IFG)	Sharp rise in prediabetes	IGT: **220%** (2011: 20.5M → 2045: 65.6M)	High risk of diabetes conversion; lifestyle interventions vital.
Mortality	Declining deaths but early-age risk	↓ **34% fewer deaths** (2011–2021); 2.8% under 60y	Improved care, but younger populations vulnerable.
Type 1 Diabetes	Steady new cases; total cases doubled	0–19y: **229.4K cases** (2021)	Pediatric care infrastructure requires scaling.
Hyperglycemia in Pregnancy	29.3% GDM prevalence (2021)	6.2M births affected	Maternal/fetal health risks; prioritize prenatal screening.
Health Expenditure	Costs nearing **$1 trillion/year**	Per-person cost: **44%** (2011: 1,274→2021:1,274→2021:1,838)	Unsustainable; cost-control strategies essential.
Demographics	Aging adult population	Adults (20–79y): **103%** (2000: 568M → 2045: 1.15B)	Higher diabetes risk due to aging; targeted geriatric care.

Sources: *Authors calculations based on the above tables*

The findings in this table are a matter of concern for global diabetes trends. Devoid cases of Liverpool were 281 percent higher from 2000 to 2045, with 53 percent not diagnosed in 2021, highlighting key screening gaps. There was a looming crisis signalled by a sharp rise in prediabetes (IGT/IFG). Deaths declined 34% (2011–2021), 2.8% among those under 60 indicating risk to younger adults. Among the drivers of the $966 billion spent on health in 2021, $866 billion of that is per person, with an unsustainable 44 percent climb since 2011. 6.2 million pregnancies (29.3% GDM), maternal/child health at risk from hyperglycemia. Compounds risks and has an ageing population (20–79 years old, up 103%). Both prevention programmes and cost controls, plus targeted care of people at high risk, must be undertaken urgently to reduce this escalating epidemic.

CHALLENGES OF TYPE 1 DIABETES IN INDIA

Public health challenges of Type 1 Diabetes (T1D) in India include delayed diagnosis, insulin inaccessibility, and substandard healthcare infrastructure. Complications of DKA and kidney failure are exacerbated by high treatment costs, poor glycaemic control, and lack of awareness. Socioeconomic burdens, as a result, prevent management, as they include stigma and financial distress. It will only increase the T1D crisis for India, which will disproportionately amplify amongst vulnerable populations, unless there are urgent reforms in policies like affordable insulin and robust primary care.

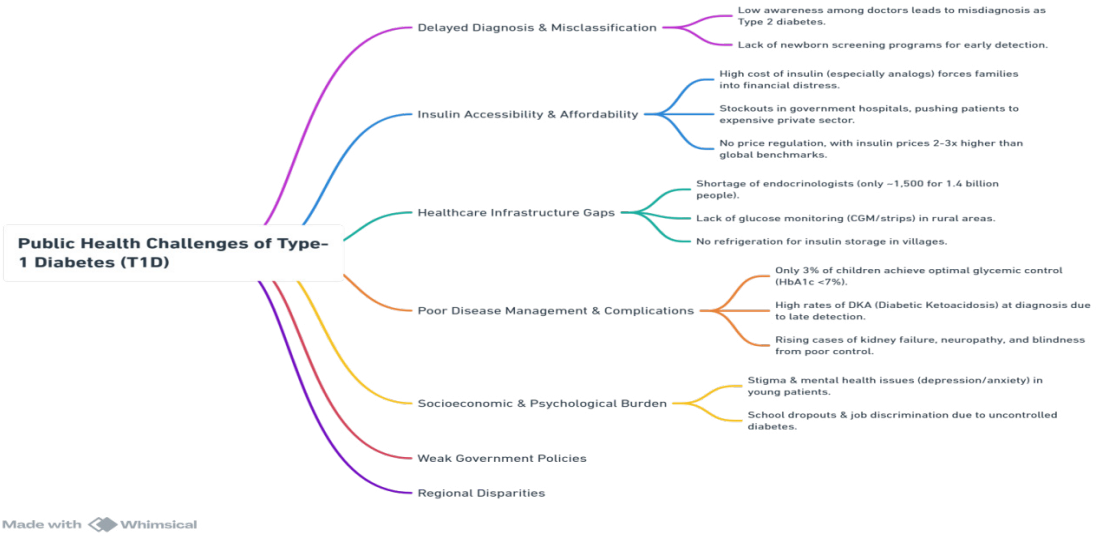

Figure 2: *Public Health Challenges of Type 1 Diabetes (T1D) in India*

Sources: *Authors' design*

Table 3: *State-wise T1D Challenges & Interventions*

State	Key Challenges	Successful Interventions	Gaps Remaining
Tamil Nadu	Rural CGM shortages	Free insulin since 1987, Diabetes Registry	Limited glucose monitoring in villages
Kerala	High out-of-pocket costs for CGMs	ASHA worker training, Govt. insulin subsidies	Affordability of advanced tech
Maharashtra	Urban slums lack access	CSR programs (e.g., Lilly's Project Samridhi)	Inequitable distribution
Delhi	Migrants miss follow-ups	AIIMS free pediatric clinic, Mohalla Clinics	Overburdened systems
Uttar Pradesh/Bihar	No free insulin, high DKA deaths	NGO support (e.g., Life for a Child)	Weak govt. infrastructure
Karnataka	Rural-urban divide	AI-based apps (BeatO), Proposed Insulin Mission	Policy implementation delays

Sources: *State Health Department, Tamil Nadu; National Health Mission Kerala. Project Samridhi and AIIMS*

Table 4: *Case Studies of Successful T1D Programs*

Program	Organization	Key Features	Impact	States Covered
Changing Diabetes in Children (CDiC)	Novo Nordisk Foundation	Free insulin, glucometers to 25,000+ kids	40% reduction in DKA deaths	Bihar, MP, Odisha, UP
Project Samridhi	Eli Lilly & Dr. Mohan's Centre	Free insulin for 5,000+, mobile rural clinics	Improved rural screening	TN, Karnataka
Insulin for Life India	Crowdfunded NGO	Redistributes unused insulin, prevents waste	Supports 3,000+ annually	Pan-India

Telangana T1D Care Network	State Govt.	Hub-and-spoke training, free HbA1c for BPL families	Strengthened district-level care	Telangana

Table 5: *Policy Recommendations by State*

State	Urgent Interventions Needed
Tamil Nadu	Scale CGM access to rural areas
Kerala	Subsidize CGMs & pumps for BPL families
Maharashtra	Mandate CSR insulin distribution in urban slums
Delhi	Migrant-focused follow-up systems
UP/Bihar	Launch state-funded insulin programs
Karnataka	Fast-track Insulin Mission implementation

SUGGESTION TO SORT OUT THESE PROBLEMS

1. Price cap on insulin & tax-free diabetes supplies.
2. Expand "Make in India" for affordable insulin & CGMs.
3. Train ASHA workers for early T1D detection.
4. Establish cold-chain systems for insulin in rural areas.
5. National T1D registry for better policy planning.

CONCLUSION

Type 1 diabetes (T1D) is a major and growing public health problem in India, and its macroeconomic consequences are considerable beyond the health outcomes of individuals. The results of this study demonstrate that T1D imposes a dual burden on healthcare systems characterised as direct healthcare expenditure plus indirect productivity losses, resulting in an overall strain on healthcare systems and a restraint on economic growth. These findings show that T1D has large, increasing direct costs of insulin therapy, medical care, and medical care complications, especially when resource constraints are present as in India. It is also compounded by the indirect costs, given by presenteeism, absenteeism, and premature mortality costs, which make the economic burden even more severe. This is perhaps the biggest threat to India's workforce productivity and economic stability: the rising prevalence of T1D and the fact that many people in India lack affordable and advanced care to treat T1D. This challenge must be addressed through a multi-tiered approach, as this means increased investment in health care infrastructure through such programmes as early diagnosis programmes and innovative treatments. Insulin is another drug that policymakers need to focus on, especially strategies like improving access to insulin and lowering out-of-pocket costs, as well as implementing workplace accommodations to support people with T1D. In brief, the macroeconomic consequences of T1D in India can be mitigated in an urgent and coordinated manner by governments, healthcare providers, and stakeholders. To relieve the economic burden and enhance the quality of life of millions of people affected by T1D, India should address both direct and indirect costs of T1D. Longitudinal studies will help future research monitor the impact of intervention on reversing the growing burden of T1D and may provide the evidence to inform evidence-based policies in combating T1D.

DECLARATIONS

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Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of Conflict

The authors declare that there are no conflicts of interest regarding this study.

Clinical Trial Number

Not Applicable

Human Ethics and Consent to Participate

Not Applicable

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