Type 2 Diabetes Mellitus in China: A Preventable Economic Burden

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Objectives: To estimate the direct and indirect costs of type 2 diabetes mellitus (T2DM) in China in 2007 and project these costs for the year 2030, and to examine and compare the benefits of selected interventions.

Study Design: Annual direct costs of medical and nonmedical care and indirect costs of income losses were estimated through case calculation of data from a cross-sectional survey carried out in 4 major Chinese cities from March 2007 to September 2007.

Methods: The subjects were consecutively recruited T2DM outpatients and inpatients from 20 secondary and tertiary hospitals using selection probability proportional to size sampling. We combined the existing data from cost-effectiveness studies into the case estimation to examine the benefits of the observed regime of interventions for preventing and treating diabetes.

Results: Annual direct medical and direct nonmedical costs per case averaged $1320.90 and $180.80, respectively. The mean annual indirect costs of T2DM and its complications were estimated to be $206.10. Based on case numbers in 2007 and projected case numbers in 2030, the direct medical costs of T2DM and its complications were estimated to be $26.0 billion in 2007 and were projected to be $47.2 billion in 2030.

Conclusions: The results indicated that T2DM consumes a large portion of healthcare expenditures and will continue to place a heavy burden on health budgets in the future. Preventive intervention, screening, and treatment strategies may effectively decrease the incidence and complications of diabetes and therefore save costs.

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For author information and disclosures, see end of text.

Nearly 200 million people worldwide (or more than 5% of the global adult population) have diabetes, and this number will increase to 333 million (or 6.3% of the global adult population) by 2025.[1] Diabetes affects persons of all ages as well as their families, while also placing heavy economic burdens on national economies and healthcare systems. Globally, the annual direct costs of diabetes, which include costs incurred for patient transport and care in addition to direct medical costs (DMCs), for people age 20 to 79 years are estimated to be at least $129 billion and as much as $241 billion or possibly more.[1] The direct costs of diabetes consume from 2.5% to 15.0% of annual healthcare budgets, depending on local prevalence and the sophistication of available treatments. In 2025, diabetes care costs are anticipated to account for between 7% and 13% of the world's healthcare budget.[1]

In China, an estimated 23.46 million people currently have diabetes[2]; that number is predicted to increase to 42.30 million by 2030.[3] Between 1996 and 2006, the prevalence of type 2 diabetes mellitus (T2DM) increased rapidly in urban China, from 4.58% to 7.67%, and was much higher in major cities (6.1%) than in small cities (3.7%) and rural areas (1.8%).[4-7] A recent study estimated the overall annual direct economic burden of diabetes among China's urban population in 2002 to be in excess of $2.44 billion.[8] In 2003, the estimate was updated to $2.29 billion for the whole population based on data from the 2003 National Health Service Investigation.[9] The annual per patient DMCs of healthcare associated with T2DM patients with complications were estimated to be $1798, compared with $484 for those without complications.[10] The treatment of chronic diseases is managed by a 3-level hospital system in Chinese urban areas. Under that system, patients chose to visit primary, secondary, or tertiary hospitals on their own, and may overuse healthcare services by selecting unnecessary high-level hospitals for diabetes treatment; it was reported that 997 (6%) tertiary hospitals nationwide consumed 54.73% of China's total healthcare expenditures.[11]

Many of the costs associated with diabetes and its complications are preventable.[12] A large number of interventions (eg, intensive blood glucose and blood pressure control, use of lipid-lowering agents, screening for and treating diabetic retinopathy, active care of feet) are known to be cost-effective, and many of these interventions also are cost-saving,[13,14]

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Take-Away Points

The economic burden of type 2 diabetes mellitus (T2DM) makes it an important clinical and public health challenge in China, requiring policymakers to determine both the current and future economic burdens of the disease to formulate effective plans for resource allocation.

- T2DM consumes a large portion of health expenditures and will continue to place a heavy burden on healthcare budgets in the future in China.
- The excessive costs are largely due to treatment of complications; therefore, the importance of preventing complications through the use of more effective treatment regimens is obvious.
- Preventive interventions, especially lifestyle intervention, in high-risk populations may effectively decrease the incidence and complications of diabetes and therefore save costs.

although controversy remains regarding the significance of the effect of some strategies (eg, intense glucose control for prevention of microvascular complications).[15-17] In recent years, 4 major trials of T2DM prevention in China,[18] Finland,[19] Sweden,[20] and the United States[21] have demonstrated that intensive lifestyle interventions involving a combination of diet and physical activity can delay or prevent diabetes among persons at high risk.

The economic burden of diabetes makes it an important clinical and public health challenge. To formulate effective plans for resource allocation, it is necessary to determine both the current and future economic burdens of the disease. The present study provides estimates of these burdens for T2DM patients in China. Cross-sectional data drawn from surveys conducted in 4 Chinese cities were used to help to determine the preventable costs under selected alternative interventions.

METHODS

Study Setting

We conducted a cross-sectional study in 4 major cities—Shanghai, Beijing, Guangzhou, and Chengdu—located in eastern, northern, southern, and western China, respectively. The **eAppendix** (available at **www.ajmc.com**) shows the locations of the cities.

Study Subjects and Sampling Design

Subjects were eligible for the study if they (1) met the 1999 World Health Organization diagnosis criteria for T2DM; (2) had received T2DM treatment for at least 1 year; (3) were age 18 years or older; (4) had lived in the city for at least 2 years; and (5) were willing and able to give written informed consent and complete the questionnaire interview.[22] The eligible subjects included outpatients and inpatients. Patients in the outpatient group were recruited consecutively from the hospitals' outpatient clinics from March 2007 to May 2007. Patients were categorized as inpatients if they were recruited from hospital wards from March 2007 to September 2007 using selection probability proportional to size sampling. Enrollment of inpatients involved 3 steps. First, using data from a previously published study that determined the proportions of complications associated with T2DM from a sample of 299 patients living in 7 Chinese urban areas, we obtained the proportion of inpatients with various complications.[8] Second, we calculated the sample size of each inpatient group stratified by type of complication, using the proportions in the previous step. Finally, we recruited the subjects consecutively for each group until the predefined sample sizes were met.

Measures

The direct costs of illness are those expenditures used to purchase medical supplies and services. In this study, direct costs are further classified as DMCs and direct nonmedical costs. Direct medical costs include all expenditures for treating T2DM and any related complications, including copayment, diagnosis, treatment, diagnostic testing, prescription drugs, and medical supplies. Direct nonmedical costs include costs for services such as transportation for the patient and family members to clinics and costs for taking care of dependents. Indirect costs refer to lost income of patients and their family members, and costs for hiring nurses or care providers.

A complication was defined as an infrequent and unfavorable evolution of a disease or a health condition that was diagnosed after the onset of T2DM.

Annual DMCs were estimated based on payment amounts for outpatient services and hospitalization; annual direct nonmedical costs were obtained from the patient's self-estimate; annual indirect costs were estimated based on sick leave days taken by patients and by family members caring for patients, average daily income in urban China, and payment for hiring nurses or care providers. Specifically, for outpatients, the annual DMC was computed as the DMC per outpatient visit multiplied by the number of outpatient visits in the past 6 months multiplied by 2 plus annual hospitalization cost. For inpatients, the annual DMC was computed as the annual DMC associated with outpatient visits plus the DMC per hospitalization multiplied by number of hospitalizations in the past 12 months. The currency was adjusted to US dollars using the exchange rate as of June 15, 2007 ($1 = 7.6948 Chinese Yuan).

Subject Recruitment and Data Collection

Study coordinators who majored in clinical medicine or preventive medicine were recruited from each study site and

trained by the investigators. The subjects were interviewed face-to-face in the hospitals using a survey designed by the School of Public Health at Fudan University. The survey included questions concerning patients' demographics, diabetes characteristics, existing complications caused by T2DM, and treatment history, as well as self-estimations of the cost of T2DM and its complications. Written informed consent was obtained from all study subjects. The Ethics Committee of the School of Public Health at Fudan University approved the study.

Statistical Analysis

All data were entered into a Chinese database (EpiData version 3.1; EpiData Association, Odense, Denmark) and transferred into SPSS 16 for statistic analyses (SPSS Inc, Chicago, IL). Categorical variables were presented as counts and percentages.

RESULTS

General Characteristics of the Study Population

A total of 2054 subjects were recruited from March 2007 to September 2007. After 14 subjects were excluded for having less than 1 year of T2DM treatment history or not providing cost information, 1524 outpatients and 516 inpatients were eligible for analysis (Table 1). The 2040 subjects ranged in age from 18 to 97 years (average age 64.2 years). More than 90% reported having some kind of medical insurance; about 70% reported a personal income below $260 per month. Among outpatients, 39.4% did not suffer complications; the median number of complications was 1 (range: 0-8). Of the 516 inpatient subjects, only 5.8% did not experience complications; the median number of complications was 3 (range: 0-10).

Table 1. General Characteristics of Subjects[a]

Characteristic	No. (%)	
	Outpatients	Inpatients
City		
Beijing	375 (24.6)	121 (23.4)
Guangzhou	376 (24.7)	127 (24.6)
Shanghai	373 (24.5)	140 (27.1)
Chengdu	400 (26.2)	128 (24.8)
Sex		
Male	637 (41.8)	231 (44.9)
Female	887 (58.2)	283 (55.1)
Lifestyle intervention		
Yes	882 (58.0)	274 (53.2)
No	640 (42.0)	241 (46.8)
Drug therapy		
Yes	1384 (90.9)	382 (74.2)
No	138 (9.1)	133 (25.8)
Insulin therapy		
Yes	506 (33.3)	358 (69.6)
No	1015 (66.7)	156 (30.4)
Medical insurance		
Urban employee insurance	1302 (85.4)	457 (88.6)
Commercial insurance	80 (5.2)	22 (4.3)
Cooperative Medical Scheme	25 (1.6)	9 (1.7)
None	117 (7.7)	28 (5.4)
Individual income		
<$260/mo	1041 (68.3)	365 (70.7)
≥$260/mo	483 (31.7)	151 (29.3)
Employed		
Yes	246 (16.2)	71 (13.8)
No	1274 (83.8)	443 (86.2)
Admission to hospital		
Secondary	196 (12.9)	163 (31.6)
Tertiary	1328 (87.1)	353 (68.4)

[a]Total number amounts may vary because of missing values.

2007 Estimation of Costs

Because the cost data were skewed, medians and quartiles were reported together with means. The DMC for each hospitalization averaged $2294.10; the DMC per outpatient visit averaged $40.70 (Table 2). Care for T2DM was associated with 7.3 ± 7.2 outpatient visits per outpatient in the past 6 months, and an average of 1.7 ± 1.4 hospitalizations for inpatients in the past 12 months. The DMC was calculated by taking into account the DMCs of the current visit and the number of outpatient visits, plus annual hospitalization costs in the past year; annualizing these sums yielded an estimated mean annual DMC of $1030.10. The corresponding sum for inpatients was $2309 per hospitalization.

Table 2. Direct and Indirect Costs for Participating Inpatients and Outpatients

Cost Item	Outpatients		Inpatients		Total	
	Mean ± SD	Median (25th-75th Percentile)	Mean ± SD	Median (25th-75th Percentile)	Mean ± SD	Median (25th-75th Percentile)
DMC per outpatient visit, $	40.70 ± 37.40	32 (18-51)	—	—	—	—
No. of outpatient visits in past 6 months	7.3 ± 7.2	6 (3-9)	1.8 ± 1.0	2 (1-2)	—	—
DMC per hospitalization, $	—	—	2294.10 ± 3970.60	1286 (907-2077)	—	—
Days per hospitalization	—	—	23.0 ± 31.6	16 (12-24)	—	—
No. of hospitalizations in past 12 months	—	—	1.7 ± 1.4	1 (1-2)	—	—
Annual hospitalization cost, $	279 ± 1377.70	0 (0-0)				
Annual DMC associated with outpatient visits, $			1642.80 ± 7698	0 (0-0)		
Annual DMC, $	1030.10 ± 1791.50	593 (249-1170)	2309 ± 5936.80	689 (0-2117)	1320.90 ± 2181.30	624 (226-1320)
Annual direct nonmedical costs, $	165 ± 470.50	8 (0-141)	277.80 ± 471.10	13 (0-252)	180.80 ± 471.30	10 (0-161)
Annual indirect costs, $	99.40 ± 505.90	0 (0-0)	515.70 ± 2767.10	0 (0-88)	206.10 ± 1477.60	0 (0-0)

DMC indicates direct medical cost.

Mean direct nonmedical costs were estimated to be $180.80 ($165 and $227.80 for outpatients and inpatients, respectively) annually. Using the 2007 urban China average per capita daily income of $10.87, the annual indirect costs of T2DM and its complications were $206.10, or $99.40 and $515.70 for outpatients and inpatients, respectively.

Economic Burden Estimation and Projection

We applied data from this sample to the Chinese population as a whole. Table 3 summarizes estimated national annual DMCs for subjects who had differing numbers of complications. For subjects with only 1 complication, more detailed subgroups are provided.

Assuming a prevalence of 23.46 million T2DM patients nationwide,[2] the estimated national DMCs for T2DM and its complications were $26.0 billion per year, or 18.2% of China's total health expenditures ($142.5 billion in 2007).[23] Using an estimated prevalence of 42.3 million T2DM patients in the year 2030, annual DMCs were projected to be $47.2 billion. Annual direct nonmedical costs for T2DM and its complications in 2007 were estimated to be $4.0 billion and projected to be $7.2 billion in 2030. Thus, the total direct costs in 2007 were $30.0 billion, which exceeded the 2003 estimate of $22.9 billion.[9] Similarly, indirect costs in 2007 were estimated to be $2.2 billion and were projected to be $4.0 billion in 2030. In total, the estimated economic cost of T2DM and its complications was $32.2 billion for 23.46 million T2DM patients in 2007 and projected to be $58.5 billion for 42.3 million T2DM patients in 2030.

Estimated Benefits of Intervention for Preventing Diabetes and Its Complications

We examined the benefits of the observed regimen of interventions to prevent and treat diabetes in China (Table 4). The World Bank determined that lifestyle interventions for preventing T2DM could reduce the incidence among persons at high risk by 35% to 58%.[13] (High-risk persons were those with either impaired glucose tolerance or T2DM, as estimated from the current cross-sectional study. Impaired glucose tolerance was defined as 2-hour glucose levels of 140-199 mg/dL [7.8/11.0 mmol] on the venous plasma glucose tolerance test.) Assuming that 95% of individuals would adhere to the program, the lifestyle interventions could result in $8.6 billion to $14.2 billion saved in T2DM health expenditures in 2030. Alternative scenarios assuming that China had the same share of indirect costs (as part of the total costs) as the United States[24] and Latin America and the Caribbean[25] yield potential total costs savings of $11.4 billion to $18.9 billion and $44.3 billion to $73.4 billion in 2030, respectively. Similarly, if using the World Bank–recommended metformin interventions for preventing T2DM in 17.2 million individuals at high risk, the incidence may be reduced by 25% to 31%, resulting in potential cost savings of $6.1 billion to $7.6 billion in 2030. If the higher US and Latin American and Caribbean shares of indirect costs were used, the interventions would save a projected $8.2 billion to $10.1 billion and $31.6 billion to $39.2 billion, respectively.

Table 3. Estimated and Projected Direct Medical Costs of Type 2 Diabetes Mellitus

Complications	Patients With Complications		DMC per Case, $		Direct Nonmedical Costs per Case, $		Indirect Costs per Case, $		2007 Estimate, Millions			2030 Projection, Millions		
	No.	%	Mean	SD	Mean	SD	Mean	SD	No.	DMC, $	Total Cost, $	No.	DMC, $	Total Cost, $
No complications	732	48.03	690.50	1209.40	137.60	458.40	69.30	434.80	11.047	7627.6	9913.1	20.317	14,028.0	18,231.4
With 1 complication														
Hypertension	41	2.69	1696.10	2329.90	268	558.60	240.60	704.10	0.631	1070.2	1391.1	1.138	1929.9	2508.6
Transient ischemic attack	17	1.12	1144.10	1317	181	333.50	25.30	61.50	0.262	299.8	353.8	0.474	542.1	639.8
Stroke	15	0.98	1143.80	1204.20	340.70	671.90	165.70	473	0.231	264.2	381.2	0.415	474.1	684.1
Acute myocardial infarction	6	0.39	1362.20	3347.80	166	203.50	0	0	0.092	125.3	140.6	0.165	224.7	252.1
Angina	99	6.50	999.10	2494.20	165.60	361.20	49.40	227.70	1.524	1522.7	1850.2	2.750	2747.1	3338.1
Congestive heart failure	19	1.25	933.60	864.90	131.80	207.90	454.20	1505	0.292	272.6	443.7	0.529	493.7	803.5
PTCA	6	0.39	3483.40	3533.90	82.50	124.60	58.10	153.70	0.092	320.5	333.4	0.165	574.7	597.9
Renal function disorders	13	0.85	850.60	721	221.80	358.20	16.10	57.80	0.200	170.1	217.7	0.360	305.8	391.4
Mass albuminuria	4	0.26	1015.50	929.50	105.70	156.50	153.70	307.40	0.062	63.0	79.0	0.110	111.7	140.2
Mini albuminuria	35	2.30	721.70	962.20	259	614.80	19	59.90	0.539	389.0	538.8	0.973	702.1	972.5
Uremia	1	0.07	215.70	—	0.50	—	0	0	0.015	3.2	3.2	0.030	6.4	6.4
Cataract	46	3.02	1299.40	2086.50	165.20	266.80	280.70	775.10	0.708	920.0	1235.7	1.277	1660.0	2229.6
Retinopathy	17	1.12	784	659.70	74.20	178.40	29.60	93	0.262	205.4	232.6	0.474	371.4	420.6
Peripheral neuropathy	100	6.56	1060.70	2347.70	160.90	404.60	114.20	645	1.539	1632.4	2055.9	2.775	2943.4	3706.8
Other CHD	7	0.46	2364.50	1286.50	174.50	229.90	0	0	0.108	255.4	274.2	0.195	460.1	494.0
Peripheral vascular disease	1	0.07	101.40	—	—	—	0	0	0.015	1.5	1.5	0.030	3.0	3.0
With 2 complications	222	14.57	1441.10	2143.50	180.80	343.30	77.50	259.50	3.417	4924.2	5806.6	6.163	8881.7	10,473.2
With 3 complications	97	6.36	2024.90	3412.80	227.70	541.50	220	684	1.493	3023.1	3691.6	2.690	5447.5	6651.9
With ≥4 complications	46	3.02	4133.20	9274.60	433.50	1219.40	65.60	203.90	0.708	2926.3	3279.7	1.277	5280.0	5917.6
Total	1524	100							23.460	26,016.6	32,223.8	42.300	47,187.2	58,462.7

CHD indicates coronary heart disease; DMC, direct medical cost; PTCA, percutaneous transluminal coronary angioplasty.

Estimated Benefits of Screening for and Treating Diabetes and Its Complications

The effectiveness and benefits of screening for and treating diabetes and its complications vary greatly (Table 5). Screening strategies to prevent T2DM among the general population may save $1.8 billion in 2030, while more specific screening or treatment strategies (ie, blood pressure control, annual screening for microalbuminuria, annual eye examination, and foot care in high-risk persons) may save even more. For example, annual eye examinations targeting 0.6 million individuals with serious vision loss may save $55 million, while foot care targeting 0.2 million persons at high risk of ulcers would save $64 million in 2030. In addition, glycemic control in persons with a glycosylated hemoglobin (A1C) value greater than 9% would reduce microvascular disease by 30% per 1% drop in A1C, thereby saving $1.2 billion in 2007 and $2.2 billion in 2030.

DISCUSSION

Although numerous cost-of-illness studies have been conducted on the estimated economic burden of diabetes in various countries, this is the first quantitative study to systematically estimate the current economic burden and project the future costs of T2DM in China. In light of increasing diabetes prevalence globally and within China, cost-of-illness studies are urgently needed to increase awareness and facilitate lobbying for resource allocation.

In China, the most recently published analysis—known as the National Health Service Investigation—estimated the

Table 4. Projected Cost Savings as a Result of Lifestyle and Metformin Interventions in 2030

Indirect Costs as a Percentage of Total Costs[a]	Program Adherence, %	Estimated Number of Cases Prevented, Millions[b]	Projected Savings, $	
			Direct Costs, Billions	Total Costs, Billions
Lifestyle intervention				
6.9 (China)	95	0.69-1.14	8.0-13.2	8.6-14.2
	50	0.36-0.60	4.2-7.0	4.5-7.5
	33	0.24-0.40	2.8-4.6	3.0-4.9
30.2 (United States)[24]	95	0.69-1.14	8.0-13.2	11.4-18.9
	50	0.36-0.60	4.2-7.0	6.0-10.0
	33	0.24-0.40	2.8-4.6	4.0-6.6
82.0 (Latin America)[25]	95	0.69-1.14	8.0-13.2	44.3-73.4
	50	0.36-0.60	4.2-7.0	23.3-38.6
	33	0.24-0.40	2.8-4.6	15.4-25.5
Metformin intervention				
6.9 (China)	95	0.49-0.61	5.7-7.1	6.1-7.6
	50	0.26-0.32	3.0-3.7	3.2-4.0
	33	0.17-0.21	2.0-2.5	2.1-2.6
30.2 (United States)	95	0.49-0.61	5.7-7.1	8.2-10.1
	50	0.26-0.32	3.0-3.7	4.3-5.3
	33	0.17-0.21	2.0-2.5	2.8-3.5
82.0 (Latin America)	95	0.49-0.61	5.7-7.1	31.6-39.2
	50	0.26-0.32	3.0-3.7	16.6-20.6
	33	0.17-0.21	2.0-2.5	11.0-13.6

[a]US and Latin American percentages reflect an assumption that China would have the same share of indirect costs as they do.
[b]The upper and lower numbers were estimated by the percent range of reduction in incidence from the World Bank report summarizing a series of cost-effectiveness studies.[13]

cost of diabetes in 2003 to be $2.29 billion.[9] This estimate, however, was obtained by national statistics data and failed to consider the burden incurred by complications, which may have been underestimated if the comorbidity of the various complications of diabetes was not considered. Another study conducted by Chen et al in 2002 estimated the urban burden from a relatively small sample of 299 patients living in 7 Chinese urban areas.[8] In the current study, we attempted to estimate the proportions of comorbidity of the various complications associated with T2DM. The magnitude of the difference between the published figure and our estimate could be largely due to the inclusion of costs related to complications and the increase of the number of cases. Our estimate of DMCs was based on a separate calculation of subgroups with different complications, which may have increased the accuracy of the medical cost estimate. In addition, we applied data from the current samples to both urban and rural patients, which may have extended the gap between the estimates and the actual health expenditure. However, the gap primarily was caused by the fact that rural patients have worse affordability difficulties than urban patients, other than the willingness-to-pay burden.[26] It may be reasonable to estimate economic burden in the whole population using the data of our samples.

We found that the proportion of direct health expenditures consumed by T2DM had been as high as 18.2%, although the total annual DMCs ($26.0 billion) were far less than those of Germany (€30.6 billion)[27] and the United States ($174 billion).[28] Prior studies reported the following costs related to T2DM as percentages of total public health expenditures: 7.4% in Spain,[29] 10.5% in Ireland,[30] 11.9% in the United States,[31] and 14.2% in Germany.[27] Because the costs incurred by T2DM in China are proportionally higher than those of developed countries, there is an urgent need for prevention programs that reduce the risks and control the complications of T2DM in China. The medical service is particularly unaffordable to the Chinese patients, who have to pay for treatment out of their own pockets with large differences under different insurance plans.[32]

■ **Table 5.** Estimated Cost Savings From Reducing Complications by Screening and Treating Diabetes and Its Complications

Strategy	Benefit of Reducing Complications	Annual DMC per Case, $	Estimated Size of Target Population, Millions	Potential Savings in Millions, $	Projected Savings by 2030 in Millions, $
Screening for T2DM in general population	25% reduction in microvascular disease	1309	General population	1005	1798
Glycemic control in persons with A1C >9%	30% reduction in microvascular disease per 1% drop in A1C	1309	8.9	1205	2158
Glycemic control in persons with A1C >8%	30% reduction in microvascular disease per 1% drop in A1C	1309	13.8	1205	2158
Blood pressure control in persons whose pressure is higher than 160/95 mm Hg	35% reduction in macrovascular and microvascular disease per 10-mm Hg drop in blood pressure	1309	6.4	2370	3481
Annual screening for microalbuminuria	50% reduction in nephropathy when ACE inhibitors are used for identified cases	1765	1.5	820	1467
Annual eye examinations	60% to 70% reduction in serious vision loss	774	0.6	31	55
Foot care in persons at high risk of ulcers	50% to 60% reduction in serious foot disease	993	0.2	35	64
Aspirin use	28% reduction in myocardial infarctions, 18% reduction in cardiovascular disease	1362, 1061	0.1	172	309
ACE inhibitor use in all persons with diabetes	42% reduction in nephropathy, 22% reduction in cardiovascular disease	1362, 1061	1.5	627	1123

A1C indicates glycosylated hemoglobin; ACE, angiotensin-converting enzyme; DMC, direct medical cost; T2DM, type 2 diabetes mellitus.

We found that indirect costs accounted for 6.9% of diabetes-related total costs in China. Our calculation of indirect costs was based on self-estimates of production losses from patients and their families. By using production losses and premature mortality, studies in other countries[28] showed that indirect costs constituted a much higher proportion of costs than our estimate, which may be partly due to the higher proportion of unemployed patients in China. An increase in accessibility to care may increase the direct costs related to diabetes, and if care is effective, this may reduce the mortality and rates of disability related to diabetes and hence reduce the economic burden of T2DM.[33]

Type 2 diabetes mellitus and its complications are preventable, and the costs of preventing and treating diabetes can be reduced. Recent studies in diverse settings have shown that lifestyle changes and metformin interventions were effective in preventing T2DM in individuals at risk, such as those with impaired glucose tolerance.[19,21,34,35] We assumed that the effectiveness of these interventions was the same in China as in developed countries but that the costs of interventions and other diabetes care were higher in developed than in developing countries. The China Da Qing Diabetes Prevention Study reported a 51% reduction in incidence as a result of lifestyle intervention in China,[34] which was consistent with the World Bank's range. Using this assumption, we found that both lifestyle and metformin interventions for preventing T2DM in China could result in substantial cost savings in anticipated health expenditures in 2030.

We projected that diabetes screening strategies for the general population would save $1.8 billion in 2030 by preventing the onset of T2DM, while more specific treatment strategies such as blood pressure control may save even more. The cost savings would result mainly because of the treatments' significant health benefits and relatively low intervention costs.

The findings in this study may be subject to several limitations. First, the study subjects were either patients recruited from outpatient clinics at secondary and tertiary hospitals or patients admitted to those hospitals, which may limit the

ability to generalize the results and overestimate the economic burden of T2DM. To obtain a more accurate estimate of T2DM burden in the healthcare setting of China, it would be preferable to conduct a community-based study in the future. Second, the cost data, especially for direct nonmedical costs and indirect costs, were based to some extent on patient recall, which may be subject to recall bias. The DMC data, however, were based primarily on medical history combined with billing information, which increased the accuracy of those estimates. The cost data for the previous 6 months also may not accurately reflect the cost data for the previous 12 months. Moreover, it is difficult to differentiate T2DM-related complications from comorbidities, particularly among the elderly, and it is possible that some patients were misdiagnosed and therefore stratified incorrectly. Finally, another limitation is that the projected results were based on a study of urban patients, who may have different disease burdens than rural patients. Further study is needed to cover the rural areas.

In conclusion, T2DM-related treatment consumes a large portion of health expenditures. The excessive costs are largely due to the treatment of complications. As diabetes prevalence in China continues to grow in the coming years, diabetes costs will continue to weigh heavily on health budgets. However, diabetes interventions among high-risk populations have the potential for considerable cost savings. As seen in this study, excessive costs increase proportional to the number of complications, so the importance of preventing complications through the use of more effective regimens is obvious.

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