Potential health and economic impact associated with achieving risk factor control in Chinese adults with diabetes: a microsimulation modelling study

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Summary
Background The prevalence of diabetes has risen sharply in China. Improving modifiable risk factors such as glycaemia and blood pressure could substantially reduce disease burden and treatment costs to achieve a healthier China by 2030.

Methods We used a nationally representative population-based survey of adults with diabetes in 31 provinces in mainland China to assess the prevalence of risk factor control. We adopted a microsimulation approach to estimate the impact of improved control of blood pressure and glycaemia on mortality, quality-adjusted life-years (QALYs), and healthcare cost. We applied the validated CHIME diabetes outcomes model over a 10-year time horizon. Baseline scenario of status quo was evaluated against alternative strategies based on World Health Organization and Chinese Diabetes Society guidelines.

Findings Among 24,319 survey participants with diabetes (age 30–70), 69.1% (95% CI: 67.7–70.5) achieved optimal diabetes control (HbA1c <7% [53 mmol/mol]), 27.7% (26.1–29.3) achieved blood pressure control (<130/80 mmHg) and 20.1% (18.6–21.6) achieved both targets. Achieving 70% control rate for people with diabetes could reduce deaths before age 70 by 7.1% (5.7–8.7), reduce medical costs by 14.9% (12.3–18.0), and gain 50.4 QALYs (44.8–56.0) per 1000 people over 10 years compared to the baseline status quo. The largest health gains were for strategies including strict blood pressure control of 130/80 mmHg, particularly in rural areas.

Interpretation Based on a nationally representative survey, few adults with diabetes in China achieved optimal control of glycaemia and blood pressure. Substantial health gains and economic savings are potentially achievable with better risk factor control especially in rural settings.

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Introduction Diabetes imposes a substantial burden of disease and consumes a significant proportion of healthcare resources worldwide—nowhere more so than in China.1 The recorded prevalence of diabetes in China has risen more than ten-fold from less than 1% in 1980 to 12.8% in 2017, and is expected to further increase as 35.2% of Chinese adults met the American Diabetes Association (ADA) criteria for pre-diabetes in 2017.2,3 Diabetes was the 6th leading cause of disability.
Research in context

Evidence before this study

Diabetes prevention and control is one of the four non-communicable diseases prioritised in the Healthy China Initiative 2019–2030. A literature search was conducted in MEDLINE using the following terms: "diabetes", "risk factor" ("control" OR "treatment"), model, and "Chin*", for articles published up until September 24, 2022. Previous studies estimated substantial gains in life expectancy and reduced cardiovascular disease with improved risk factor control in China. However, these studies used simulated risk factor levels at baseline that may not reflect a representative sample of Chinese adults or data before 2010; and either applied non-Asian models known to overpredict complications in Chinese populations or limited outcomes to myocardial infarction and stroke. Compared to other high-income countries like the US, China has a much lower proportion of adults who achieved risk factor control targets for blood pressure and glycaemic control.

Added value of this study

Using a contemporaneous risk simulation model developed and validated in Chinese populations, we estimate the potential health gains and cost savings in 31 scenarios based on global clinical guidelines and across a range of control rates. Analysing a nationally representative cross-sectional survey of the mainland Chinese population conducted in 2018–19, this study finds that few adults with diabetes in China achieved optimal control for glycaemia and in particular blood pressure, with disparities observed between urban and rural residents. We estimate that achieving 70% control of the WHO/Chinese Diabetes Society targets will reduce mortality before age 70 by 7.1%, increase quality-adjusted life-years by 50.4 per 1000 people and save health-care costs by 14.9%. The largest health gains were for strategies involving strict blood pressure control of 130/80 mmHg, particularly when aimed at rural residents. Our modelling study provide contemporaneous evidence on the potential impact of various diabetes control scenarios on health and economic burdens in China.

Implications of all the available evidence

The health and economic burden of poor risk factor control for individuals with diabetes in China is substantial and potentially avoidable by achieving the control targets in the Healthy China 2030 action plan. Expanding and improving provision of health care beyond the current 32.9% of people with diabetes being treated as of 2018 will incur costs, thus offsetting some of the cost savings from delayed progression and averted complications. Additional health care spending could be justifiable considering the projected cost savings when risk factor control is achieved, in addition to the reduced health burden. Previous studies in East Asia suggest increased health spending on diabetes care and hypertension has a positive net value, indicating cost increases have been more than offset by quality improvements from reduced mortality. The factors that can cause inadequate risk factor control such as adherence and self-management warrant particular attention and further research.

adjusted life years (DALYs) lost in China in 2016, having risen from 22nd place in 1990; diabetes-related mortality rates increased by 63.5% and attributable DALYs increased by 95% over this period.6,7 Improving modifiable risk factors such as glycaemia and blood pressure could substantially reduce disease burden and treatment costs, yet despite the increasing prevalence of diabetes in China over the past few decades; rates of awareness, treatment, and control remain low, imposing a heavy burden both on population health and the economy. In 2018, 66.8% of US adults with diagnosed diabetes achieved risk factor control targets for hemoglobin A1c (HbA1c) and 48.2% achieved blood pressure control; compared to China, where only 32.9% of people with diabetes reported being treated for hyperglycemia, and only 50.1% of those receiving treatment had adequate glycemic control.8

Major policy initiatives to tackle diabetes have been championed globally and locally to tackle the rising health and economic burden of diabetes. The WHO global action plan for prevention and control of non-communicable diseases (2013–2020) called for a 25% reduction in premature mortality from diabetes by 2025.9 The Central Committee of the Communist Party and the State Council released the Healthy China 2030 blueprint to attain the health indicator performance achieved by high-income countries by 2030.10 The Healthy China 2030 action plan set an even more ambitious goal of a 30% decrease in the premature death rate from diabetes compared to 2015 levels, an awareness rate of diabetes of 60%, and a standard management rate of 70%.11 The Diabetes Prevention and Control Action plan, one of the four non-communicable diseases prioritized in the Healthy China 2030 Initiative, aims for greater standardization of diabetes management and strengthen control of risk factors.12

Previous estimates suggest substantial gains in life expectancy with improved management in China, such as an average increase of 3.2 years per-capita with complete adherence13; but these estimates were based on simulated cohorts that utilized risk equations derived from a 1970s UK cohort (UKPDS, UK Prospective Diabetes Study) known to overpredict mortality and cardiovascular risk in Asian populations.14,15 Given the limitations of previous studies, we contribute to the literature by utilizing a nationally representative survey in mainland China to analyze the prevalence of
inadequate risk factor control and associated sociodemographic factors among people with diabetes. To inform population-based strategies for achieving the Healthy China 2030 goals, we applied a contemporary risk simulation model developed and validated in Chinese populations to estimate the potential health and economic impact of various scenarios of improved risk factor control.

**Methods**

**Study design**

We conducted a microsimulation analysis to estimate mortality, quality-adjusted life-years (QALYs) gained and health-care cost savings from reducing macrovascular and microvascular complications among people with diabetes in China (Fig. 1). We applied the CHIME (Chinese Hong Kong Integrated Modelling and Evaluation) microsimulation model on individual-level data to estimate the effect of increased control of glycaemia and blood pressure in 31 scenarios based on clinical guidelines from China, USA, UK and WHO (World Health Organization) across a range of control rates (Fig. 1, Table 1). These individual-level outcomes over a ten-year period are weighted and aggregated to derive the population estimates.

**Participants**

Analyses were performed on participants with diabetes aged 30–70 years. We used nationally representative cross-sectional data from the China Chronic Disease and Nutrition Surveillance (CCDNS), collected from August 2018 to June 2019 at 298 national disease surveillance points in 31 provinces in mainland China. Details of the CCDNS sampling method, data collection, and quality control have been described previously. In brief, the CCDNS study was designed to assess the national profile of chronic diseases and related risk factors using a multistage stratified cluster-randomised sampling design. It has been conducted every 3–5 years since 2004 on community-based Chinese residents who have been living in their current residence for at least 6 months in the 12 months before the survey. Data collected included demographics, education, occupation, household income, urban/rural residence, clinical biomarkers, diabetes-related complications, and prescribed medications. Urban residency was defined as living in urban subdistricts and rural residency as living in rural townships.

**Simulated scenarios**

Risk factor strategies was defined according to clinical guidelines from WHO/Chinese Diabetes Society (CDS)/American Diabetes Association (ADA) (HbA1c < 7% [53.0 mmol/mol] and blood pressure < 130/80 mm Hg), UK National Institute for Health and Care Excellence (NICE) (HbA1c 6.5% [48 mmol/mol] and blood pressure 140/80 mmHg), strict targets (HbA1c < 6.5% [48 mmol/mol] and blood pressure < 130/80 mmHg), and loose targets (HbA1c < 7% [53 mmol/mol] and blood pressure < 140/90 mmHg [Table 1]).

The scenarios simulated individual and combined control of glycaemia and blood pressure. The impact of inadequate risk factor control was evaluated by
comparing immediate control (values of risk factors were assumed to reach the corresponding target at the first year) to status quo baseline values over a 10-year time horizon. Progression of other physiological variables, such as BMI, was assumed to remain constant over the duration of the analyses, to allow comparisons of the potential impact of different risk factor targets. This modelling approach leads to conservative estimates as risk factor values typically deteriorate over time in the baseline scenario. Similar to other contemporary diabetes modelling studies, we did not simulate to a specific lipid biomarker concentration, given current evidence favoring risk-based treatment rather than target-based treatment.\(^2\) We simulated scenarios where 70%, 80% and 100% of participants achieve control of targets and also a 20 percentage point increase in the control rate from baseline levels.

Outcomes
We calculated outcomes including mortality before 70 years of age, and quality adjusted life-years. Quality adjustment of life years was calculated by taking the baseline utility value for type 2 diabetes without complications and adding the disutility for each occurring condition to create annual utility values per individual. Utility values for diabetes and its complications were taken from a recently published meta-analysis of Asian participants.\(^2\) Annual direct medical costs associated with diabetes-related complications in China were derived from a rapid review of recent published sources detailed below.

Literature review of cost estimates
We searched the EMBASE and MEDLINE (OVID) databases from Jan 1, 2018 to Sep 16, 2021 for the keywords: “diabetes”, “healthcare cost”, and “China” (see Appendix). We included studies reporting medical or treatment costs of type 2 diabetes and its complications in mainland China. The search and data extraction were independently conducted by two researchers with cross-checking and discrepancies resolved by consensus. Medical costs presented in US dollars were converted to Chinese Yuan (RMB) using the currency exchange rate in the corresponding year of study.

Details of the study characteristics and cost estimates identified in the literature review are shown in Appendix Fig. S1 and Appendix Tables S1 and S2. We used Duan et al. as the preferred model input as cost estimates were reported by year of onset and presence of existing disease with adjustment for age, sex, insurance, location, and comorbidities.\(^2\) However, the study participants only covered the urban population, namely the urban employee basic medical insurance (UEBMI) or urban resident basic medical insurance (URBMI) schemes.\(^2\) Estimates of medical costs in rural settings were scarce with no cost estimates identified for half of the diabetes-related complications. For complications that were not reported by Duan et al., we used estimates derived from urban populations reported by He et al. for neuropathy and retinopathy,\(^2\) and Wang et al. for amputation.\(^2\) Model input for total annual direct medical costs of type 2 diabetes and related complications are shown in Appendix Table S3.

Statistical analysis and modelling
The prevalence of optimal risk factor control among people with diabetes was calculated accounting for the complex sampling weight, stratification, and clustering. Estimates for HbA1c, blood pressure and combined control were computed for the overall sample and by subgroups of age, sex, and urban/rural residency. Multivariable logistic regression was used to analyze the demographic and socioeconomic factors (age, sex, urban or rural residence, household income, occupation, and education level) associated with achieving optimal risk factor control individually and combined.

We applied a microsimulation modelling approach using the CHIME (Chinese Hong Kong Integrated Modelling and Evaluation) model to estimate the projected health and economic burden for each participant with diabetes.\(^1\) The CHIME model is an individual-level discrete-time outcomes model for diabetes and related complications derived and validated in Chinese (East Asian) populations. Details of the CHIME model have been previously described.\(^1\) Individual-level inputs are entered in the simulation to estimate the probability of each outcome in the 1-year cycle; if the individual is predicted to survive the 1-year cycle, then the individual’s age, duration, history of events, and risk factor values are used to predict the occurrence of outcomes in the next annual cycle. The discrete-time cycles are repeated sequentially for 10 years. The CHIME model was developed using Hong Kong SAR Hospital Authority data (97,628 participants) from 2006 to 2017, and externally validated against the China Health and Retirement Longitudinal Study (CHARLS; 4567 participants) from 2011 to 2018 and nine published trials: Acarbose Cardiovascular Evaluation (ACE), Action to Control Cardiovascular Risk in Diabetes (ACCORD), Action in Diabetes and Vascular disease: preterAx and diamicron-MR Controlled Evaluation (ADVANCE), Diabetes Prevention Program (DPP), Japan Diabetes Complications Study (JDCS), Japan Elderly Diabetes Intervention Trial (J-EDIT), Japanese Primary Prevention of Atherosclerosis with Aspirin for Diabetes trial (JPAD), and UK Prospective Diabetes Study 33 and 80 (UKPDS 33 and 80).

The outcomes modeled include cumulative incidence and time to onset of complications, life expectancy, quality-adjusted life expectancy, and direct costs arising from treatment of diabetes-related complications. The 12 health outcomes in the CHIME model were all-cause mortality, diabetes-related macrovascular events (myocardial infarction, ischemic heart disease,
heart failure, cerebrovascular disease), and microvascular events (peripheral vascular disease, neuropathy, amputation, ulcer of the skin, chronic kidney disease, cataracts, retinopathy).

We did not impute missing data at baseline as the data was complete for 97.8% of participants (Appendix Table S4). We ran 50 simulations modelling a total of 1.19 million individuals for each of the risk factor control strategies. Estimates were weighted to represent the Chinese adult population in 2018 (National Bureau of Statistics of China) with confidence intervals accounting for the complex sampling weight, stratification, and clusters using the R ‘survey’ package. All analyses were done in R version 4.0.

**Ethical approval**
The CCDNS study was approved by the ethical review committee of the National Center for Chronic and Non-communicable Disease Control and Prevention, China CDC (approval number 201819). Written informed consent was obtained from all CCDNS participants.

**Role of the funding source**
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

**Results**
Our study included 24,319 participants with diabetes in the CCDNS 2018–19 survey; baseline characteristics are shown in Appendix Table S5. A total of 532 participants (<2.2%) were missing data at baseline and were excluded from the eligible study participants (Appendix Table S4). The mean age of participants in the 2018–19 survey was 53.2 years (95% CI: 52.8–53.6) and 43.2% (41.8–44.6) of participants were female. Urban residents accounted for 61.8% (56.5–67.2) of the study sample with 93.7% being of Han ethnicity (91.8–95.5). Mean BMI was 26.3 kg/m² (26.1–26.4), mean HbA1c was 6.8% (6.7–6.8), mean systolic and diastolic blood pressure was 138.2 mmHg (137.5–138.9) and 82.2 mmHg (81.7–82.6) respectively.

Table 2 shows in 2018–19 the weighted prevalence of people with diabetes who achieved optimal control defined by WHO/Chinese Diabetes Society targets for both glycaemia (HbA1c < 7% [53 mmol/mol] and blood pressure < 130/80 mmHg was 20.1% [18.6–21.6]). The weighted prevalence was higher in women (23.4% [21.6–25.2]) than in men (17.6% [15.8–19.4]); and higher in urban areas (21.9% [19.8–24.0]) compared to rural areas (17.2% [15.7–18.7]). The weighted prevalence of glycaemic control (HbA1c < 7% [53 mmol/mol]) was higher at 69.1% (67.7–70.5%) than blood pressure control (<130/80 mmHg) at 27.7% (26.1–29.3%). Control of glycaemia and blood pressure was higher among females than males, and control of blood pressure tended to be higher for urban residents than rural residents in both sexes (Fig. 2). Appendix Table S6 shows blood pressure control was negatively associated with age (50–59 years: odds ratio (OR) = 0.61 [0.47–0.78]; 60–70 years: OR = 0.49 [0.39–0.63] and positively associated with female sex (OR = 1.69 [1.41–2.03]), urban residence (OR = 1.16 [1.01–1.33]) and tertiary education (OR = 1.46 [1.18–1.80]). No significant associations were observed for glycemic control. However, results of effect modification show that the associations by age groups differ among males and females (Appendix Table S7).

<table>
<thead>
<tr>
<th>SBP (mmHg)</th>
<th>All</th>
<th>Male</th>
<th>Female</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;120</td>
<td>27.7 (26.1–29.3)</td>
<td>24.7 (22.6–26.9)</td>
<td>31.7 (29.7–33.7)</td>
<td>23.8 (22.0–25.5)</td>
<td>30.2 (28.0–32.4)</td>
</tr>
<tr>
<td>&gt;120</td>
<td>55.9 (54.0–57.9)</td>
<td>54.3 (51.9–56.7)</td>
<td>58.1 (55.8–60.4)</td>
<td>52.1 (49.9–54.4)</td>
<td>58.3 (55.6–60.9)</td>
</tr>
</tbody>
</table>

Table 2: Weighted percentage of adults with controlled diabetes and hypertension among adults with diabetes in 2018–19.
Changes in health and economic outcomes from immediate control of risk factors compared to status quo baseline levels over a 10-year period are shown in Table 3, and by sex and urban/rural residence in Fig. 2 and Appendix Table S8. There were considerable variations in potential improvements, with more than a five-fold difference in improvements between the most and least effective strategy. For example at a 70% control rate, the strict risk factor target strategy (HbA1c < 6.5% and BP < 130/80 mmHg) achieved the greatest improvements of 7.5% (6.0–9.2) reduction in mortality before age 70, utility gains of 52.0 QALYs (46.2–57.8) per 1000 people, and direct cost savings of 21.5% (14.7–28.1%) over 10 years; compared to looser targets (HbA1c < 7.0% and BP 130/80 mmHg) which is projected to achieve 3.8% (3.0–4.8) reduction in mortality before age 70, utility gains of 28.8 QALYs (25.2–32.5) per 1000 people, and direct cost savings of 9.7% (7.9–11.8); or a single target of BP < 140/90 mmHg which is projected to achieve 1.2% (0.9–1.6) reduction in mortality before age 70, utility gains of 10.0 QALYs (8.6–11.4) per 1000 people, and direct cost savings of 2.7% (2.2–3.4). Control of blood pressure alone (<130/80 mmHg) was associated with greater potential reductions in mortality before age 70, utility gains (31.5 [27.5–35.5] per 1000 people), and cost savings (7.4% [6.0–9.1]) than glycemic control alone (HbA1c < 6.5%; 1.3% reduction in mortality before age 70, 9.3 QALY gains per 1000 people, cost savings of 5.1%).

Higher control rates were associated with greater health improvements. Achieving 100% control of the
WHO/Chinese Diabetes Society targets of HbA1c < 7% and blood pressure < 130/80 mmHg was projected to reduce mortality before age 70 by 11.4% (9.2–14.0), with associated utility gains of 80.6 QALYs (71.7–89.6) per 1000 people and cost savings of 23.8% (19.7–28.8); whereas 70% control was estimated to lead to a 7.1% (5.7–8.7) reduction in mortality before age 70, utility gains of 50.4 QALYs (44.8–56.0) per 1000 people, and direct cost savings of 14.9% (12.3–18.0) over 10 years. A 20-percentage point increase in control rates from baselines levels yielded comparable health benefits despite initial population control rates at baseline varying from 17.4% for the strictest targets (HbA1c < 6.5% and BP 130/80 mmHg) to 69.1% for HbA1c < 7% (53 mmol/mol).

Greater potential reductions in mortality and greater QALY gains were projected among rural residents than urban ones, particularly among females (Fig. 3, Appendix Table S8). Strategies involving strict blood pressure control to <130/80 mmHg, either standalone or combined with glycemic control (WHO/Chinese Diabetes Society and strict control), were associated with greater reductions in mortality and QALY gains than other strategies.

Discussion
Using a nationally representative cross-sectional survey (CCDNS) of the mainland Chinese population, we estimated that only 1 in 5 people with diabetes achieved

<table>
<thead>
<tr>
<th>Control rate</th>
<th>Strategy</th>
<th>Reduction in mortality before age 70, %</th>
<th>QALY gain per 1000 people</th>
<th>Medical cost reduction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>BP &lt; 130/80</td>
<td>7.1 (5.5–9.0)</td>
<td>53.9 (47.0–60.8)</td>
<td>12.6 (10.3–15.5)</td>
</tr>
<tr>
<td></td>
<td>BP &lt; 140/90</td>
<td>3.8 (2.8–5.0)</td>
<td>31.3 (26.8–35.8)</td>
<td>8.5 (6.7–10.6)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 6.5%</td>
<td>4.2 (3.1–5.6)</td>
<td>31.0 (26.3–35.7)</td>
<td>17.0 (12.9–20.8)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 7%</td>
<td>4.4 (3.3–5.7)</td>
<td>29.8 (25.1–34.6)</td>
<td>11.9 (9.6–14.6)</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>7.5 (5.9–9.5)</td>
<td>57.0 (49.8–64.3)</td>
<td>19.2 (15.7–23.4)</td>
</tr>
<tr>
<td></td>
<td>NICE</td>
<td>8.1 (6.5–10.1)</td>
<td>60.6 (53.8–67.3)</td>
<td>23.0 (18.8–28.0)</td>
</tr>
<tr>
<td></td>
<td>WHO</td>
<td>11.4 (9.2–14.0)</td>
<td>80.6 (71.7–89.6)</td>
<td>23.8 (19.7–28.8)</td>
</tr>
<tr>
<td></td>
<td>Strict</td>
<td>11.7 (9.4–14.5)</td>
<td>81.6 (72.5–90.6)</td>
<td>27.9 (23.1–33.7)</td>
</tr>
<tr>
<td>80%</td>
<td>BP &lt; 130/80</td>
<td>5.1 (4.0–6.5)</td>
<td>39.0 (34.0–44.0)</td>
<td>9.1 (7.4–11.2)</td>
</tr>
<tr>
<td></td>
<td>BP &lt; 140/90</td>
<td>2.1 (1.5–2.7)</td>
<td>17.1 (14.6–19.5)</td>
<td>4.6 (3.7–5.8)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 6.5%</td>
<td>2.3 (1.6–3.0)</td>
<td>16.5 (14.0–19.0)</td>
<td>9.1 (7.4–11.1)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 7%</td>
<td>1.5 (1.2–2.0)</td>
<td>10.5 (8.9–12.2)</td>
<td>4.2 (3.4–5.1)</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>5.0 (3.9–6.3)</td>
<td>38.2 (33.4–43.3)</td>
<td>12.9 (10.5–15.7)</td>
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<td>5.7 (4.6–7.0)</td>
<td>42.4 (37.7–47.1)</td>
<td>16.1 (13.2–19.6)</td>
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<tr>
<td></td>
<td>WHO</td>
<td>8.5 (6.9–10.5)</td>
<td>60.5 (53.7–67.2)</td>
<td>17.9 (14.8–21.6)</td>
</tr>
<tr>
<td></td>
<td>Strict</td>
<td>8.9 (7.1–11.0)</td>
<td>61.9 (55.0–68.7)</td>
<td>21.2 (17.5–25.6)</td>
</tr>
<tr>
<td>70%</td>
<td>BP &lt; 130/80</td>
<td>4.1 (3.2–5.3)</td>
<td>31.5 (27.5–35.5)</td>
<td>7.4 (6.0–9.1)</td>
</tr>
<tr>
<td></td>
<td>BP &lt; 140/90</td>
<td>1.2 (0.9–1.6)</td>
<td>10.0 (8.6–11.4)</td>
<td>2.7 (2.2–3.4)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 6.5%</td>
<td>1.3 (0.9–1.7)</td>
<td>9.3 (7.9–10.7)</td>
<td>5.1 (4.2–6.2)</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>3.8 (3.0–4.8)</td>
<td>28.8 (25.2–32.5)</td>
<td>9.7 (7.9–11.8)</td>
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<td></td>
<td>NICE</td>
<td>4.5 (3.6–5.5)</td>
<td>33.3 (29.6–37.0)</td>
<td>12.7 (10.4–15.4)</td>
</tr>
<tr>
<td></td>
<td>WHO</td>
<td>7.1 (5.7–8.7)</td>
<td>50.4 (44.8–56.0)</td>
<td>14.9 (12.3–18.0)</td>
</tr>
<tr>
<td></td>
<td>Strict</td>
<td>7.5 (6.0–9.2)</td>
<td>52.0 (46.2–57.8)</td>
<td>17.8 (14.7–21.5)</td>
</tr>
<tr>
<td>20 percentage point increase from baseline</td>
<td>BP &lt; 130/80</td>
<td>2.0 (1.5–2.5)</td>
<td>14.9 (13.0–16.8)</td>
<td>3.5 (2.8–4.3)</td>
</tr>
<tr>
<td></td>
<td>BP &lt; 140/90</td>
<td>1.7 (1.2–2.3)</td>
<td>14.2 (12.2–16.2)</td>
<td>3.8 (3.1–4.8)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 6.5%</td>
<td>2.0 (1.4–2.6)</td>
<td>14.5 (12.3–16.6)</td>
<td>8.0 (6.5–9.7)</td>
</tr>
<tr>
<td></td>
<td>HbA1c &lt; 7%</td>
<td>2.8 (2.1–3.7)</td>
<td>19.3 (16.3–22.4)</td>
<td>7.7 (6.2–9.4)</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>2.5 (1.9–3.1)</td>
<td>18.8 (16.4–21.2)</td>
<td>6.3 (5.2–7.7)</td>
</tr>
<tr>
<td></td>
<td>NICE</td>
<td>2.4 (2.0–3.0)</td>
<td>18.1 (16.1–20.2)</td>
<td>6.9 (5.6–8.4)</td>
</tr>
<tr>
<td></td>
<td>WHO</td>
<td>2.8 (2.3–3.5)</td>
<td>20.2 (17.9–22.4)</td>
<td>6.0 (4.9–7.2)</td>
</tr>
<tr>
<td></td>
<td>Strict</td>
<td>2.8 (2.3–3.5)</td>
<td>19.7 (17.5–21.9)</td>
<td>6.8 (5.6–8.2)</td>
</tr>
</tbody>
</table>

Strict: HbA1c < 6.5% (48 mmol/mol) and BP < 130/80 mmHg; UK NICE: HbA1c < 6.5% (48 mmol/mol) and BP < 140/90 mmHg; WHO/ADA: HbA1c < 7% (53 mmol/mol) and BP < 140/90 mmHg; ADA, American Diabetes Association; BP, blood pressure; CDS, Chinese Diabetes Society; HbA1c, glycated hemoglobin; UK NICE, National Institute for Health and Care Excellence; QALY, quality-adjusted life years; WHO, World Health Organization.

Table 3: Mortality, quality-adjusted life years and medical cost at 10 years.
Fig. 3: Change in health outcomes at 10 years by strategy. Reduction in mortality before age 70. Strict: HbA1c < 6.5% (48 mmol/mol) and BP < 130/80 mmHg, UK NICE: HbA1c < 6.5% (48 mmol/mol) and BP < 140/90 mmHg, WHO/CDS/ADA: HbA1c < 7% (53 mmol/mol) and...
the recommended target for glycaemia and blood pressure in 2018–19. We found fewer people with diabetes met their blood pressure control targets than for glycaemia. Achievement of glycemic control was consistent across age groups, sex, and urban/rural residence at around 70%; however, less than one-third of people with diabetes had optimal control of blood pressure.

Our modelling found that achieving control of blood glucose and blood pressure in people with type 2 diabetes was associated with substantial health gains, reductions in early deaths and medical cost savings. If 70% of people with diabetes achieved control, there was still a two-fold difference between the least stringent targets of HbA1c < 7% and blood pressure < 140/80 mmHg compared to adopting the most stringent international targets of HbA1c < 6.5% and blood pressure < 130/80 mmHg. A particular focus on improving blood pressure management is warranted as the current control rates are low among people with diabetes. Our findings suggest substantial health gains from strategies that include strict blood pressure control targets, particularly when aimed at rural residents. Achieving 70% control at the current WHO/Chinese Diabetes Society targets of HbA1c < 7% and blood pressure < 130/80 mmHg was estimated to cut deaths before age 70 by 7.1% and direct medical costs by 14.9% over the next 10 years; higher control rates were associated with even greater gains.

Risk factor control in China was still lower than some high-income countries, such as the USA, where 66.8% and 48.2% of adults with diagnosed diabetes achieved targets for HbA1c and blood pressure, but higher than low-income and middle-income countries where 52.6% and 16.3% of adults being treated for diabetes achieved HbA1c and blood pressure control.12,21 The potential health gains and economic savings from improved risk factor control, such as poor glycemic control, have been shown elsewhere.12,13,20,29 Studies on UKPDS participants indicated that HbA1c was not the driving factor in reducing the incidence of complications, with reductions in blood pressure shown to provide significant benefits.10,11 A previous study estimated optimal management of type 2 diabetes in China can improve life expectancy by an average of 3.2 years in the total population; however, these estimates used simulated cohorts of individuals with notably worse baseline risk factor values than the nationally representative 2018–19 CCDNS participants in this study.21 Furthermore, the underlying risk prediction used in the IQVIA model were based on the UKPDS Outcomes Model version 1 that has higher predicted event rates for complication than the newer UKPDS Outcomes Model version 2—itself shown to overpredict complications in Chinese populations.14 More recent studies using the IQVIA model in Sweden have reported far more modest gains in life expectancy.20 Our estimates of the quality-adjusted life-years gained from achieving the WHO targets are comparable to another study using disability-adjusted life-years estimates in low-income and middle-income countries in East Asia.

Our microsimulation analysis provides valuable insight for diabetes control plans in China. Diabetes prevention and control is one of the four non-communicable diseases prioritized in the Healthy China Initiative 2019–2030; a key component of the action plan is to implement treatment standards to strengthen management, reduce complications, and improve quality of life.19,20 This large-scale national study on the prevalence of risk factor control in people with diabetes in China highlights the health and economic burden that is potentially avoidable by improved risk factor control. Importantly, expanding and improving the provision of healthcare above the 32.9% of people with diabetes currently being treated in 2018 will incur additional costs, offsetting some of these estimated cost savings from delayed progression and averted complications.7 Further healthcare spending could be justifiable as previous studies in East Asia, such as rural Zhejiang and the economically developed Hong Kong Special Administrative Region of China showed increased health spending on diabetes care and hypertension had a positive net value, indicating cost increases have been more than offset by quality improvements from reduced mortality.23,24 The underlying reasons for inadequate risk factor control such as adherence and self-management warrant attention. Further research on implementation strategies and their cost effectiveness in China will be crucial to help health policy makers and public health practitioners reduce the health and economic burden from inadequate risk factor control and achieve the goal of a healthier China.

Our study had several limitations. First, we cannot distinguish between type 1 and type 2 diabetes, though type 1 diabetes was estimated to account for less than 5% of total cases.26 Second, we also lacked contemporary estimates for direct medical costs in rural areas and applied the same pricing as urban areas to assess relative changes, which may overestimate actual costs in rural areas. Third, an inherent limitation for all health economic modelling analyses is the uncertainty around predicting future outcomes. Given the chronic pathophysiology and long-term management of diabetes,
modelling is unavoidable to analyze long-term health and economic outcomes; indeed, some benefits of risk factor control for type 2 diabetes are only observed over the long term. For example, significant benefits in cardiovascular outcomes with intensively controlled HbA1c were not observed until after 10 years for UKPDS.\textsuperscript{18,19} We applied a recent health economic outcomes model of type 2 diabetes for Chinese populations that was externally validated against a nationally representative sample of Chinese residents (CHARLS: China Health and Retirement Longitudinal Study) and nine diabetes trials.\textsuperscript{20} The use of a contemporaneous validated model using constant parameter inputs (other than HbA1c and blood pressure) during the simulations reduces modelling uncertainty and focuses on the differences between risk factor strategies. A further limitation is that these analyses did not account for potential treatment-related adverse effects, such as hypoglycemia or hypotension, when aiming for lower target levels, and these effects should be considered when assessing individualized therapies.\textsuperscript{21}

Conclusions
Diabetes is one of four non-communicable diseases prioritized for prevention and control in the Healthy China Initiative 2019–2030. Analyzing a nationally representative survey conducted in 2018–19, this study found few adults with diabetes in China achieved optimal control for glycaemia and particularly blood pressure with disparities between urban and rural residents. The health and economic burden of poor risk factor control among people with diabetes in China is substantial and potentially avoidable by achieving the control targets in the Healthy China 2030 action plan.

Contributors
JQ, ZZ, and MZ had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. JQ and MZ conceived and designed the study. ZZ, HYHK, and SZ contributed to data collection. JQ, CSN, KE, GML, and MZ interpreted the data. JQ obtained funding. JY, RM, XJO, HYHK, and SZ provided administrative, technical, or material support. KE and MZ supervised the study. JQ and MZ drafted the manuscript. All authors critically reviewed the manuscript and approved the final version before submission.

The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Data sharing statement
The data that support the findings of this study are available from National Center for Chronic and Non-communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention (China CDC) but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of China CDC. Data access requests for CCDNS 2018–19 should be addressed to the National Center for Chronic and Non-communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention (China CDC), Xicheng District, 100 050, Beijing, China.

Declaration of interests
The authors declare that they have no competing interests.

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Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lancp.2023.100690.

References


