Heliyon 8 (2022) e09461

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Economic hardships from COVID-19 and its association with socioeconomic factors and diabetes management indicators: A cross-sectional study

Yiqian Xin [a,b,1], Ege K. Duman [a,1], Xinyi Yan [a], Enying Gong [a,c], Shangzhi Xiong [a,d], Xinyue Chen [a], Truls Østbye [a,b], Lijing L. Yan [a,*]

[a] Global Health Research Center, Duke Kunshan University, Kunshan, Jiangsu Province, China
[b] Duke Global Health Institute, Duke University, Durham, North Carolina, USA
[c] School of Population and Global Health, University of Melbourne, Victoria, Australia
[d] The George Institute for Global Health, Faulty of Medicine and Health, University of New South Wales, Sydney, Australia

ARTICLE INFO

Keywords:
COVID-19
Pandemic
Financial toxicity
Income loss
Diabetes management

ABSTRACT

Aims: The three objectives of this study were to determine the economic hardships of COVID-19 pandemic, their socio-economic predictors, and their association with diabetes management indicators in three cities in a middle-income country.

Methods: A community-based cross-sectional survey of 309 people with diabetes aged 34–85 was carried out in 10 communities during July and August 2020. Face-to-face surveys were conducted by trained community physicians. Economic hardship was assessed by income loss and "financial toxicity" during the COVID-19 pandemic, where financial toxicity was defined as experiencing economic difficulties in accessing diabetes management resources. Indicators of diabetes management was assessed by blood glucose and Hemoglobin A1c (HbA1c) monitoring frequency.

Results: Among all respondents, 38.5% reported having income loss, and 15.5% experiencing financial toxicity during the pandemic. Younger and self-employed people living suburban areas were more likely to experience income loss. Similarly, suburban area residency and lower household income were associated with financial toxicity. Patients with financial toxicity were less likely to monitor HbA1c in the past three months (OR = 0.20; 95% CI, 0.07–0.48).

Conclusion: Diabetes management as indicated by less frequent HbA1c monitoring was associated with experiencing COVID-19 related financial toxicity. Our findings identified vulnerable groups in need of additional support for diabetes management.

1. Introduction

The COVID-19 pandemic caused by SARS-CoV-2 coronavirus [1] has engendered substantial challenges against the economies and healthcare systems around the globe. To this end, national governments and organizations have adopted novel economic and clinical policies and guidelines in their attempts to address emergent issues caused by the pandemic and its sequela [2, 3, 4, 5]. While the pandemic's direct impacts on the economy and the healthcare systems of nations have been extensively studied [6, 7], its effects on particular patient populations also deserve research attention. Hence, the pandemic's economic effects on patients with diabetes ought to be studied since a strong clinical relationship between type 2 diabetes mellitus and COVID-19 has been previously discovered and the pandemic is likely to have considerable impacts on self-management of diabetes in such populations.

Multiple studies prior to ours have found that people with diabetes are at raised risk for COVID-19 infections and are more likely to develop more severe infections with higher mortality as compared to those in people without diabetes [8, 9]. Furthermore, many studies have heretofore confirmed that diabetes is one of the most common morbidities found in patients with COVID-19 [10, 11, 12, 13]. One study in particular found that COVID-19 resulted in persistent hyperglycemia in 35% of the study population and in worse clinical outcomes and longer hospital stays [14]. Additionally, a report from the Chinese Center for Disease Control

* Corresponding author.
E-mail address: lijing.yan@duke.edu (L.L. Yan).
[1] Yiqian Xin and Ege K. Duman contributed equally to this work.

https://doi.org/10.1016/j.heliyon.2022.e09461
Received 30 July 2021; Received in revised form 28 January 2022; Accepted 12 May 2022

and Prevention on 72314 COVID-19 cases found that the case-fatality rate which was calculated to be 2.3% in patients who did not present comorbidities was 7.3% in people with diabetes [15]. The same report also found the case-fatality rate to be significantly elevated in older patients with COVID-19, making the situation even more worrisome as the prevalence of diabetes increases with age [16].

The pandemic's impact on people with diabetes is not limited by an increase in the risk of infection and morbidity levels since lockdowns and quarantines also have considerable effects on diabetes management among those who are not infected with the virus. A study of Australia's response to the pandemic reported a significant reduction in access to usual diabetes care due to reallocation of clinical resources and staff for COVID-19 specific activities and fear of exposure to SARS-CoV-2 [17]. Similarly, a US study reported that laboratory tests for many people with diabetes have either been canceled or postponed, and their clinical appointments have also been canceled, postponed, or switched to virtual appointments [18]. Moreover, a study conducted in Northern India reported a decrease in self-monitoring of blood glucose levels and exercise and an increase in carbohydrate intake in people with diabetes over the 45-day lockdown [19]. Another study using a simulation model predicted the duration of lockdown in India to be directly proportional to worsening in diabetes management and subsequent increase in complications [20]. One study collecting pre- and post-lockdown data from 110 patients via direct regular interviews during their visits to a diabetes clinic found no causal relationship between the pandemic and a major change in overall glycemic control of patients [21]. Contrarily, another study from Southern India reported that 81% of their study population was unsatisfied with their glycemic control and 76% of type 2 diabetes patients did not consult or meet a physician during the lockdown mainly because of the high cost of care [22].

Despite these interrelationships between diabetes and COVID-19, there is a major gap in our knowledge about the economic effects of the COVID-19 pandemic on people with diabetes which could have substantial impact on diabetes care and management of patients. To address this gap, this study aims to assess the economic hardship of COVID-19 pandemic, evaluate the socioeconomic factors associated with the hardship, and further investigate changes in management of type 2 diabetes mellitus patients associated with economic hardships.

2. Methods

2.1. Participants and procedure

This cross-sectional survey (entitled "Impact of COVID-19 Pandemic on Diabetes Management and eHealth", ICoDe) was a stand-alone study based on a community-based cohort study (entitled "Mechanisms and Path Analyses for Health Management among Chronic Diseases Patients: A Community Empowerment-Based Approach", CEBA). The baseline survey of CEBA was conducted in the summer of 2019 before the COVID-19 pandemic. In the original CEBA cohort, people with hypertension and/or diabetes were enrolled from 12 communities in three cities in a middle-income country, where random sampling was conducted based on the electronic health record system of the community health stations with the following criteria: (1) age ≥45 years; (2) diagnosis of hypertension and/or diabetes from a registered health facility; (3) having lived in one of the 12 communities for at least nine months and having no plans to move out for at least another month; (4) providing informed consent. The CEBA study further excluded participants with terminal diseases, those who were unable to communicate with researchers due to physical or mental disability, pregnant women, and those who had family members already enrolled in the project.

The present cross-sectional study (ICoDe) was conducted during the summer of 2020, inviting the enrolled CEBA participants who were diagnosed with diabetes in the 10 communities in two cities to participate. Two community health physicians in each community (20 physicians in total) who had been trained regarding the rationale and contents of the questionnaire conducted the survey. Most (>90%) surveys were completed in person, the rest via telephone during July and August 2020 when the COVID-19 pandemic was mitigated. All eligible individuals were invited via phone by community physicians to participate in this study. Data were collected via the electronic questionnaire platform, Qualtrics (Qualtrics, Provo, UT).

2.2. Questionnaire and variables

The questionnaire used in the present ICoDe study was designed to address the issues engendered by the COVID-19 pandemic among people with diabetes. There were 46 questions in the survey that were divided into five sections: demographic information, COVID-19 pandemic information, history of diabetes treatment and management, change of diabetes treatment and management due to COVID-19, and e-Health utilization before and during the pandemic.

We assessed economic hardships of COVID-19 pandemic through two measures, income loss and financial toxicity. Income loss was defined as "loss of income experienced by the participant or a member of the participant's immediate family as a result of COVID-19 pandemic." Financial toxicity was defined as "having experienced difficulties in accessing medication or treatment for diabetes due to financial hardships since the COVID-19 crisis" in the questionnaire. "Financial toxicity", a term frequently used in literature on cancer [23, 24], in this paper, aims to assess the participants' economic barriers in accessing and utilizing clinical and healthcare resources more efficiently. This is also in line with the more prevalent yet broad definition of the term: patient-level economic impact of disease and treatment costs [25]. Accordingly, in this study, the term "financial toxicity" refers to the financial hardship engendered by the pandemic that directly affects the participant's access to diabetes medication and treatment was utilized to report the extent to which the financial burden engendered by the COVID-19 pandemic impacts the patients' ability to access these resources. Both income loss and financial toxicity were dichotomous variables, categorized as "yes" and "no". The two self-reported indicators of diabetes management, infrequent (less than once a month) blood glucose monitoring and HbA1c monitoring for the past three months, were similarly dichotomous.

Participants were asked about their socioeconomic status, including age, sex, household income, residency, marital status, household size, highest education level, and occupation. Among these, sex, marital status, occupation, and highest education level were directly used from the baseline survey of CEBA as sex and highest education level were assumed unchanged unless otherwise specified, while the status of occupation and marital status before the COVID-19 pandemic were needed in the analysis. The household monthly income was categorized into "less than US $1,500", "$1,500–3,000" and "more than $3,000". The residency region included "suburban areas" and "urban areas". The marital status was categorized into "married" and "single" (including never married, widowed, divorced or other). The highest education level was grouped to "below primary education", "primary education", and "secondary education or above" as only 2.0% respondents reported an education level of college or above. Occupation categories included "white collar worker", "blue-collar worker", "self-employed individual", and "retired, unemployed individual or others".

2.3. Statistical analysis

The basic characteristics of the participants were described as means and standard deviations (SDs) or percentages by economic hardships and diabetes management indicators. To determine whether socioeconomic status (independent variables) was associated with the economic hardship (dependent variables) in the COVID-19 pandemic, we performed multivariable logistic regression analyses to calculate odds ratios (ORs) for income loss and financial toxicity during the pandemic. Chi-squared (χ^2) tests were performed to assess the bi-variable associations between economic hardship during the pandemic and diabetes management indicators. We also used logistic regression models to calculate ORs for infrequent glucose monitoring and HbA1c monitoring in the past three months with economic hardships as independent variables, adjusting for age, sex, the region of residency, occupation, highest education level, marital status, household size and household income. All ORs were reported with 95% confidence intervals (CIs), with significance defined as $P < 0.05$. All analyses were performed using R version 4.0.2 and verified by another analyst using STATA version 16.0 (StataCorp LLC).

2.4. Ethical consideration

The study was approved by the Institutional Review Board of Duke Kunshan University and all participants provided written informed consents.

3. Results

3.1. Description of the study sample

Among a total of 328 people with diabetes (all eligible individuals) who were approached via phone for their willingness to participate in the cross-sectional survey, sixteen were excluded: one had died, seven were lost to follow-up, and eight refused to participate, with the response rate of the ICoDe survey being 95.1%. Three others were also excluded due to the lack of confirmed diagnosis of diabetes. The remaining 309 eligible patients were included in the analysis. The sample selection process is shown in Figure 1.

The basic characteristics of this cross-sectional study (ICoDe) population by economic hardship are shown in Table 1. Of the 309 patients included in the analysis, 147 were male and 162 were female. People who were younger (Mean: 61.03, SD: 7.50), lived in suburban areas (46.6%), had bigger household size (Mean: 3.60, SD: 2.20), and were self-employed (73.3%) tended to be subjected to income loss during the COVID-18 pandemic. Similarly, people who lived in suburban areas (22.5%) were more likely to experience financial toxicity during the pandemic. Characteristics of the sample were also assessed by indicators of diabetes management (Table 2). People who lived in urban areas (89.3%) and white collar (90.0%) or blue color workers (89.8%) were more likely to monitor blood glucose more than once per month. People who lived in urban areas (56.5%), had smaller household size (Mean: 2.86, SD: 1.26), and had less household income (<$1,500 per month) were more likely to report monitoring HbA1c in the past three months.

3.2. Economic hardships and indicators of diabetes management

People with income loss were more likely to have financial toxicity from COVID-19 verified by chi-squared test. Among all participants, 15.5% (95% CI, 11.7–20.1%) had financial toxicity during COVID-19 pandemic. Among patients with income loss, a significantly higher prevalence of financial toxicity was reported (28.8%; 95% CI, 20.8–37.9%), while among those without income loss, only 7.1% (95% CI, 3.8–11.8%) had financial toxicity, with P-value < 0.001.

Participants with different economic hardship had significant differences in their behaviors of HbA1c monitoring (Figure 2). People with income loss during the pandemic were significantly less likely than those without income loss to monitor their HbA1c values in the past three months (26.1% vs. 38.6%; $P = 0.033$). Similarly, compared with those without financial toxicity, people with financial toxicity were less likely to monitor their HbA1c values in the past three months (10.4% vs. 37.1%; $P = 0.001$). However, no significant difference in monthly glucose monitoring was observed between people with and without income loss and financial toxicity during the pandemic.

3.3. Multivariate analysis

Results of multivariable logistic regression models to evaluate the association between sociodemographic factors and economic hardships are presented in Table 3. Younger age (OR = 0.93 per year; 95% CI, 0.90–0.96), residency of suburban areas (OR = 2.08; 95% CI, 1.33–3.28) and self-employment (OR = 6.34; 95% CI, 1.37–32.41) were associated with higher risk of income loss during the pandemic after adjustment for all the covariates. People who lived in suburban areas were more likely to be subject to financial toxicity during the pandemic (OR = 4.87; 95% CI, 2.52–10.20). In addition, household income of less than US $1,500 per month was significantly associated with financial toxicity (OR = 2.81; 95% CI, 1.07–8.53).

Table 4 presents the adjusted association of indicators of diabetes management with economic hardships. After adjusting for sociodemographic factors, financial toxicity was no longer associated with infrequent blood glucose monitoring (OR = 1.66; 95% CI, 0.83–3.21). However, people with financial toxicity were still significantly less likely to monitor their HbA1c in the past three months (OR = 0.20; 95% CI, 0.07–0.48). In addition, living in suburban areas, and having no white-collar jobs were significantly related to no HbA1c monitoring in the past three months.

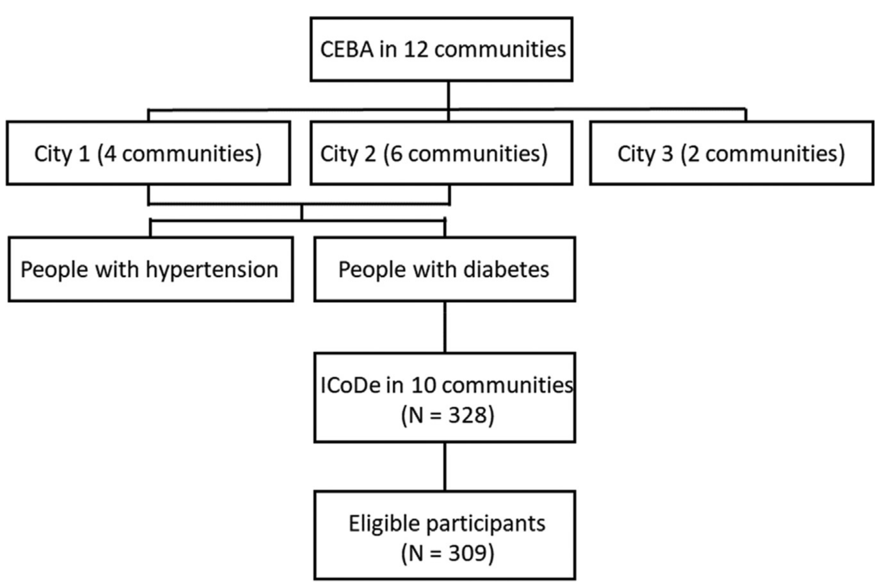

Figure 1. Flowchart of the current study. Abbreviations: CEBA: Mechanisms and Path Analyses for Health Management among Chronic Diseases Patients: A Community Empowerment-Based Approach; ICoDe: Impact of COVID-19 Pandemic on Diabetes Management and eHealth.

Table 1. Characteristics of the study population by economic consequences of COVID-19.

	Total	Income loss		Financial toxicity[a]	
		No	Yes	No	Yes
No. of participants	309	184	119	261	48
Age, mean (SD), year	63.13 (7.89)	64.28 (7.78)	61.03 (7.50)	62.95 (8.06)	63.94 (6.70)
Sex, %					
Male	47.6	61.4	38.6	88.4	11.6
Female	52.4	60.7	39.3	80.6	19.4
Residency, %					
Urban	42.4	70.9	29.1	93.8	6.2
Suburban	57.6	53.4	46.6	77.5	22.5
Marital status, %					
Single	10.0	53.3	46.7	80.0	20.0
Married	90.0	61.5	38.5	84.8	15.2
Household size, mean (SD)	3.30 (1.79)	3.11 (1.45)	3.60 (2.20)	3.30 (1.85)	3.31 (1.48)
Occupation, %					
White collar worker	3.24	60.0	40.0	80.0	20.0
Blue-collar worker	15.86	48.9	51.1	87.8	12.2
Self-employed	4.85	26.7	73.3	86.7	13.3
Retired, unemployed or others	76.05	65.4	34.6	83.7	16.3
Highest education level, %					
Below primary	38.51	63.8	36.2	81.4	18.6
Primary	17.15	54.7	45.3	77.4	22.6
Secondary or above	44.34	60.4	39.6	89.7	10.3
Monthly Household income, %					
More than US$ 3,000	11.97	58.3	41.7	89.2	10.8
UD$ 1,500–3,000	37.86	55.3	44.7	84.5	15.5
Less than US$ 1,500	50.16	65.4	34.6	83.1	16.9

[a] Financial toxicity is defined as having economic problems from COVID-19 affecting diabetes management.

Table 2. Characteristics of the study population by indicators of diabetes management.

	Total	Monthly glucose monitoring		HbA1c monitoring in the past three months	
		No	Yes	No	Yes
No. of participants	309	49	260	207	102
Age, mean (SD), year	63.13 (7.89)	63.88 (7.53)	63.00 (7.96)	63.41 (7.90)	62.57 (7.87)
Sex, %					
Male	47.6	12.9	87.1	67.4	32.7
Female	52.4	18.5	81.5	66.7	33.3
Residency, %					
Urban	42.4	10.7	89.3	43.5	56.5
Suburban	57.6	19.7	80.3	84.3	15.7
Marital status, %				100.0	
Single	10.0	9.7	90.3	64.5	35.5
Married	90.0	16.6	83.5	67.3	32.7
Household size, mean (SD)	3.30 (1.79)	3.47 (1.32)	3.27 (1.87)	3.27 (1.87)	2.86 (1.26)
Occupation, %					
White collar worker	3.24	10.0	90.0	40.0	60.0
Blue-collar worker	15.86	10.2	89.8	73.5	26.5
Self-employed	4.85	26.7	73.3	80.0	20.0
Retired, unemployed or others	76.05	16.6	83.4	66.0	34.0
Highest education level, %					
Below primary	38.51	13.5	86.6	66.4	33.6
Primary	17.15	26.4	73.6	79.3	20.8
Secondary or above	44.34	13.9	86.1	62.8	37.2
Monthly Household income, %					
More than US$ 3,000	11.97	21.6	78.4	94.6	5.4
US$ 1,500–3,000	37.86	13.7	86.3	70.9	29.1
Less than US$ 1,500	50.16	16.1	83.9	57.4	42.6

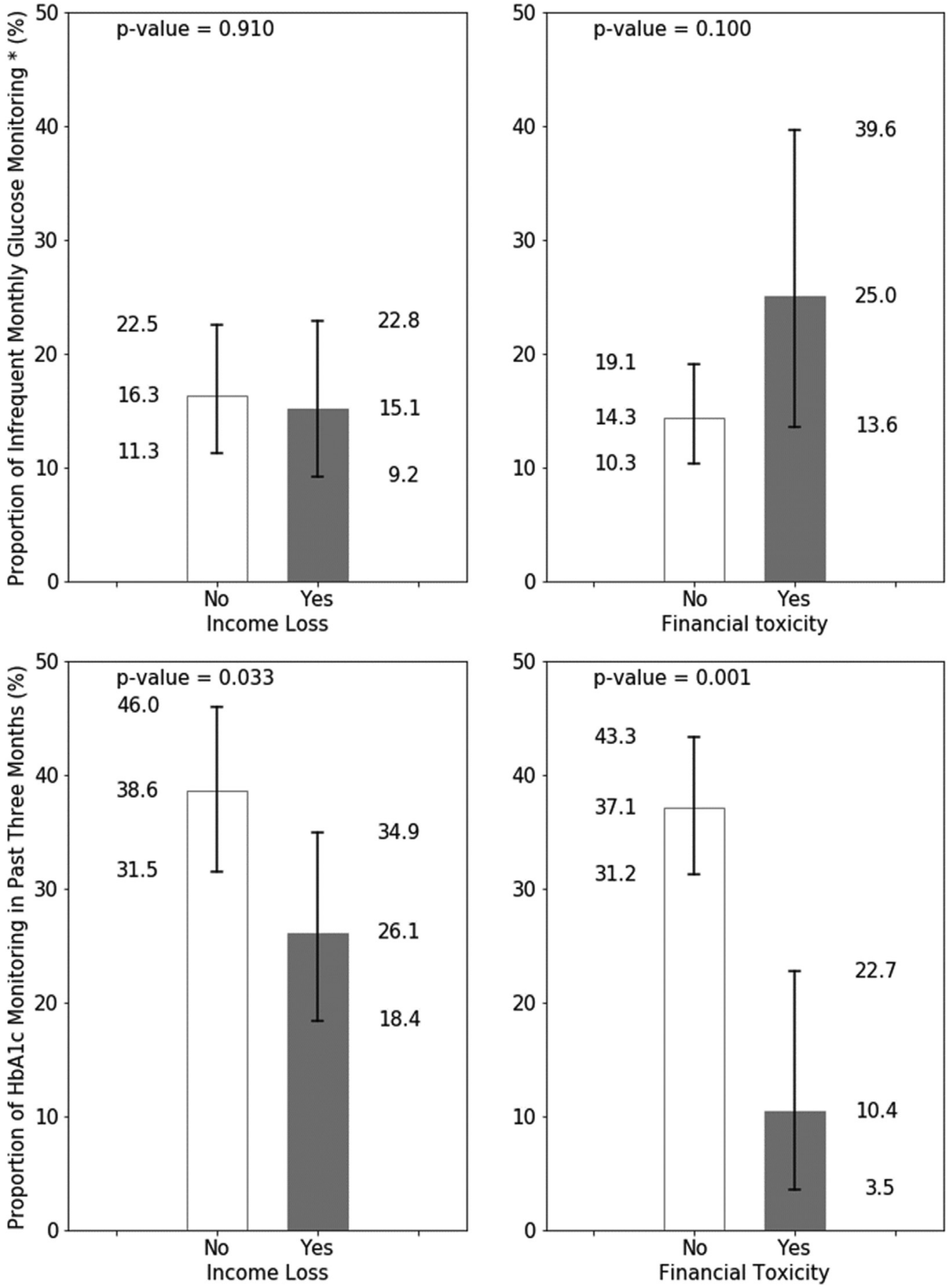

Figure 2. Distribution of indicators of diabetes management by economic consequences with 95% confidence intervals. *In the top panels, the y axis indicated proportion of infrequent monthly glucose monitoring (i.e. having glucose monitoring less than once per month).

4. Discussion

Our study found that economic hardships were prevalent among people with diabetes during COVID-19 pandemic. Younger age, living in suburban areas, self-employment, and lower household income (< US $1,500 per month) were significantly associated with severer economic hardships. Neither of the economic variables was associated with monthly glucose monitoring, while patients with financial toxicity were less likely to have monitored HbA1c in the past three months.

In our study, by utilizing several sociodemographic indicators, we investigated the economic impact of the COVID-19 pandemic on people with diabetes and the extent to which it restricts the access to treatment and medication for diabetes management. To the best of our knowledge, this constituted a significant knowledge gap as the literature lacked any prior research addressing this exact issue. In our survey, 38.5% and 15.5% of all respondents reported experiencing income loss and financial toxicity, respectively. Our study population did not contain any known COVID-19 infected members at the time of surveying and the study was

Table 3. Associations of demographic factors with economic consequences during the pandemic, OR (95% CI)[a].

	Income loss	Financial toxicity[b]
Age	0.93 (0.90, 0.96) ***	1.00 (0.96, 1.05)
Sex		
Male	Ref	Ref
Female	1.04 (0.66, 1.63)	1.72 (0.96, 3.15)
Residency		
Urban	Ref	Ref
Suburban	2.08 (1.33, 3.28) **	4.87 (2.52, 10.20) ***
Marital status		
Single	Ref	Ref
Married	0.54 (0.27, 1.10)	0.88 (0.37, 2.24)
Household size	1.12 (0.98, 1.29)	0.98 (0.82, 1.14)
Occupation		
White collar worker	Ref	Ref
Blue-collar worker	1.69 (0.47, 6.29)	0.33 (0.07, 1.94)
Self-employed	6.34 (1.37, 32.41) *	0.31 (0.04, 2.26)
Retired, unemployed or others	1.33 (0.39, 4.89)	0.38 (0.09, 2.07)
Highest education level		
Below primary	Ref	Ref
Primary	1.14 (0.61, 2.11)	1.41 (0.67, 2.91)
Secondary and above	0.73 (0.43, 1.25)	0.66 (0.32, 1.36)
Monthly Household income		
More than US$ 3,000	Ref	Ref
US$ 1,500–3,000	1.22 (0.60, 2.50)	2.17 (0.84, 6.48)
Less than US$ 1,500	0.96 (0.47, 2.01)	2.81 (1.07, 8.53) *

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
[a] Every column represents an individual model, including variables listed with OR and 95% CI. We calculated ORs of having income loss or financial toxicity during COVID-19 pandemic.
[b] Financial toxicity was defined as having economic problems affecting diabetes management.

conducted in China where the pandemic was relatively more successfully kept under control. For instance, only 87 accumulated cases of COVID-19 had appeared in our study location with a population of 80 million prior to our survey which was conducted in the summer of 2020 [26,27]. Accordingly, our findings highlight that the economic impact of the pandemic on people with diabetes is not negligible as the pandemic disproportionately affect populations with diabetes both in terms of infection rates, and management of diabetes as compared to those without diabetes.

We similarly found that both indicators of economic hardships were more prevalent in patients living in suburban areas as compared to those living in urban areas. Some factors that possibly contribute to these findings are the differences between urban and suburban areas in the number of job opportunities, the number of remote working opportunities, and in policies depending on the location of the patients. Similarly, younger age and self-employment status were found to be significantly associated with income loss during the pandemic. Since both factors can be correlated with less financial stability, it is not surprising to see how COVID-19 has economically affected those falling under these groups to a further extent. In addition, those falling into the lowest of the three household income categories reported slightly higher financial toxicity although they reported the least income loss among the three groups. This finding further suggests that especially for low-income patients living in suburban areas, even comparatively less income loss might induce comparably higher financial toxicity. Although there might be further factors affecting this relation, low-income patients prioritizing basic life needs in their spending, and suburban areas lacking sufficient clinical infrastructure, resources, and preparedness for pandemic in hospital and virtual settings possibly contribute substantially. Furthermore, job loss or depreciation of businesses could also be contributing factors and therefore require attention for research. Since there were no studies prior to ours to investigate these correlations in-depth, however, further research ought to be conducted to validate our results. Regardless, we were able to identify younger, self-employed, and suburban diabetes patients as financially vulnerable groups in the face of the COVID-19 pandemic.

We found that experiencing financial toxicity was associated with less HbA1c monitoring (OR = 0.20; 95% CI, 0.07–0.48). Similarly, patients living in suburban areas reported less likelihood of getting HbA1c monitoring over the three months before our study was conducted (OR = 0.20; 95% CI, 0.12–0.33). It is crucial to note that HbA1c is an essential tool in assessing metabolic control in diabetes [28, 29]. Accordingly, these findings fall in line with those of previous studies investigating the impact of COVID-19 pandemic on diabetes management. Multiple groups have associated the pandemic with poorer overall diabetes management [17, 18, 19, 20, 21, 22]. In our case, however, we have distinctively identified residential status as a significant factor for HbA1c monitoring, which was associated with financial toxicity. Our results regarding the lessened HbA1c monitoring in patients experiencing financial toxicity indicate that the economic repercussions of the pandemic on people with diabetes could manifest as or result in financial toxicity when they engender problems concerning the management of diabetes. Even though there have been no prior studies on people with diabetes regarding the financial toxicity engendered by the pandemic to validate our findings, our results conform with studies conducted on different cancer survivor and patient populations which revealed that financial hardships invoked by the COVID-19 crisis further exacerbated the costs of cancer treatment and engendered financial toxicity [30, 31]. Similarly, our results indicate that when the economic repercussions of the pandemic affect the management of diabetes, people with diabetes experience further financial toxicity.

We found the COVID-19 pandemic's economic impact on people with diabetes and its effects on diabetes management to be prevalent and substantial. Similarly, we associated the economic impact and its effects on diabetes management, for which we used the term "financial toxicity", with several sociodemographic factors. Nonetheless, interpretation of our results should still be cautiously made due to several limitations. Our patient population was limited in size and residential diversity as the surveys were conducted in only two cities. Thus, although the study samples were randomly selected from an existing cohort, representativeness and generalization of the study results should be carefully considered. Similarly, the causal direction between the economic hardships of the COVID-19 pandemic and diabetes management is difficult to infer from this study alone due to its cross-sectional nature and a possibility of recall bias stemming from the use of self-reported data. Lastly, no health indicators related to diabetes were included in this study as outcomes. Accordingly, future studies should consider including these indicators as outcomes in assessing the effects of COVID-19 pandemic on people with diabetes.

Experiencing pandemic related financial toxicity was especially common in low-income patients and patients living in suburban areas and was associated with worse diabetes management as indicated by lessened HbA1c control. While the sociodemographic factors we investigated were few in number, our study managed to identify several vulnerable populations for future policy interventions. To these ends, we believe that further research should identify vulnerable groups from regions which have implemented different policies during pandemic to better inform future policies in measuring and acknowledging the financial burden experienced by vulnerable populations with diabetes.

We end by discussing approaches for improving diabetes care, although our study did not directly address these issues. Research focusing on diabetes management to optimize the treatment outcomes in patients diagnosed with diabetes and COVID-19 ought to be furthered.

Table 4. Associations of economic consequences and demographic factors with indicators of diabetes management during the pandemic, OR (95% CI)[a].

Income loss	Infrequent glucose monitoring[b]		HbA1c monitoring in the past three months[c]	
No	Ref	–	Ref	–
Yes	0.78 (0.43, 1.42)	–	0.83 (0.50, 1.39)	–
Financial toxicity				
No	–	Ref	–	Ref
Yes	–	1.66 (0.83, 3.21)	–	0.20 (0.07, 0.48) **
Age	1.01 (0.97, 1.06)	1.01 (0.97, 1.06)	1.01 (0.97, 1.04)	1.00 (0.97, 1.04)
Sex				
Male	Ref	Ref	Ref	Ref
Female	1.81 (1.01, 3.30)	1.63 (0.92, 2.93)	1.12 (0.68, 1.86)	1.19 (0.72, 1.97)
Residency				
Urban	Ref	Ref	Ref	Ref
Suburban	2.28 (1.23, 4.35) *	1.77 (0.95, 3.35)	0.16 (0.10, 0.26) ***	0.20 (0.12, 0.33) ***
Marital status				
Single	Ref	Ref	Ref	Ref
Married	2.42 (0.88, 8.42)	2.49 (0.91, 8.64)	0.62 (0.27, 1.41)	0.53 (0.23, 1.22)
Household size	1.02 (0.86, 1.19)	1.04 (0.88, 1.20)	0.96 (0.80, 1.13)	0.94 (0.77, 1.10)
Occupation				
White collar worker	Ref	Ref	Ref	Ref
Blue-collar worker	0.72 (0.12, 8.25)	0.96 (0.17, 10.89)	0.12 (0.03, 0.53) *	0.08 (0.02, 0.35) **
Self-employed	2.41 (0.36, 29.33)	2.58 (0.39, 31.27)	0.09 (0.01, 0.49) *	0.06 (0.01, 0.34) *
Retired, unemployed or others	1.34 (0.27, 14.33)	1.55 (0.31, 16.58)	0.14 (0.03, 0.55) *	0.10 (0.02, 0.40) **
Highest education level				
Below primary	Ref	Ref	Ref	Ref
Primary	3.14 (1.50, 6.60) *	2.99 (1.44, 6.25) *	0.43 (0.20, 0.89)	0.46 (0.22, 0.96)
Secondary and above	1.43 (0.69, 2.97)	1.50 (0.74, 3.09)	0.93 (0.52, 1.68)	0.84 (0.46, 1.52)
Monthly Household income				
More than US$ 3,000	Ref	Ref	Ref	Ref
US$1,500–3,000	0.54 (0.23, 1.33)	0.54 (0.22, 1.31)	5.52 (1.55, 29.41) *	6.44 (1.76, 35.68) *
Less than US$ 1,500	0.84 (0.36, 2.04)	0.79 (0.34, 1.93)	8.84 (2.48, 47.28) *	11.69 (3.18, 64.93) **

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
[a] Every column represents an individual model, including variables listed with OR and 95% CI.
[b] We calculated ORs of having infrequent glucose monitoring (i.e. having glucose monitoring less than once per month).
[c] We calculated ORs of having HbA1c monitoring in the past three months.

Recent research showed promising results for Sitagliptin treatment at the time of hospitalization as compared to standard care in patients with type 2 diabetes and COVID-19 [32]. Furthermore, telemedicine visits were shown to prevent disruptions in medication prescribing and improve glycemic control throughout the pandemic for people with diabetes [33]. Therefore, we also propose to explore telemedicine visits and other digital health technology as a potential area for research to address possible loss of access and efficiency in diabetes management during the pandemic. Because telemedicine visits and some digital technology are more affordable than traditional clinic or hospital-based care, they may yield more desirable clinical outcomes but also help address the issue of financial toxicity that we dissect in this paper. Our study population did not have anyone who contracted COVID-19; nevertheless, future research focusing on people with both diabetes and COVID-19 is needed to improve their health status.

Declarations

Author contribution statement

Yiqian Xin: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ege K. Duman: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Enying Gong and Truls Østbye: Conceived and designed the experiments; Wrote the paper.

Shangzhi Xiong and Lijing L. Yan: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Xinyue Chen: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Xinyi Yan: Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

The authors do not have permission to share data.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

[1] Y. Wu, et al., SARS-CoV-2 is an appropriate name for the new coronavirus, Lancet 395 (10228) (2020) 949–950.
[2] P. Wilkins, D. Gilchrist, J. Phillimore, Independent review of emergency economic stimulus measures: global Financial Crisis and COVID-19, Aust. J. Publ. Adm. (2020) **n/a**(n/a).
[3] G.R. Wilensky, Policy lessons from our covid experience, N. Engl. J. Med. 383 (17) (2020) e96.
[4] J. Cloyne, et al., COVID-19 and the economy, Fisc. Stud. 41 (2) (2020) 257–258.
[5] M. Gupta, et al., COVID-19 and economy, Dermatol. Ther. 33 (4) (2020) e13329.
[6] Fund I.I.M., World Economic Outlook: the Great Lockdown, 2020. Washington, DC.
[7] L. Song, Y. Zhou, The COVID-19 pandemic and its impact on the global economy: what does it take to turn crisis into opportunity? China World Econ. 28 (4) (2020) 1–25.
[8] C.H. Mazucanti, J.M. Egan, SARS-CoV-2 disease severity and diabetes: why the connection and what is to be done? Immun. Ageing 17 (2020) 21.
[9] A. Shenoy, M. Ismaily, M. Bajaj, Diabetes and covid-19: a global health challenge, BMJ Open Diabetes Res. Care 8 (1) (2020).
[10] W.-j. Guan, et al., Clinical characteristics of coronavirus disease 2019 in China, N. Engl. J. Med. 382 (18) (2020) 1708–1720.
[11] C. Huang, et al., Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China, Lancet 395 (10223) (2020) 497–506.
[12] J.-j. Zhang, et al., Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China, Allergy 75 (7) (2020) 1730–1741.
[13] X. Yang, et al., Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study, Lancet Respir. Med. 8 (5) (2020) 475–481.
[14] L. Montefusco, et al., Acute and long-term disruption of glycometabolic control after SARS-CoV-2 infection, Nature Metabol. 3 (6) (2021) 774–785.
[15] Z. Wu, J.M. McGoogan, Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese center for disease control and prevention, JAMA 323 (13) (2020) 1239–1242.
[16] S. Wild, et al., Global prevalence of diabetes: estimates for the year 2000 and projections for 2030, in: Diabetes Care, 2004, p. 1047+.
[17] S. Andrikopoulos, G. Johnson, The Australian response to the COVID-19 pandemic and diabetes - lessons learned, Diabetes Res. Clin. Pract. 165 (2020) 108246.
[18] L. Fisher, et al., The early impact of the COVID-19 pandemic on adults with type 1 or type 2 diabetes: a national cohort study, J. Diabet. Complicat. 34 (12) (2020) 107748.
[19] A. Ghosh, et al., Effects of nationwide lockdown during COVID-19 epidemic on lifestyle and other medical issues of patients with type 2 diabetes in north India, Diabetes Metabol. Syndr. 14 (5) (2020) 917–920.
[20] S. Ghosal, et al., Estimation of effects of nationwide lockdown for containing coronavirus infection on worsening of glycosylated haemoglobin and increase in diabetes-related complications: a simulation model using multivariate regression analysis, Diabetes Metabol. Syndr. 14 (4) (2020) 319–323.
[21] P. Sankar, et al., Effects of COVID-19 lockdown on type 2 diabetes, lifestyle and psychosocial health: a hospital-based cross-sectional survey from South India, Diabetes Metabol. Syndr. 14 (6) (2020) 1815–1819.
[22] J.J. Olickal, et al., Effect of COVID19 pandemic and national lockdown on persons with diabetes from rural areas availing care in a tertiary care center, southern India, Diabetes Metabol. Syndr. 14 (6) (2020) 1967–1972.
[23] S.Y. Zafar, et al., The financial toxicity of cancer treatment: a pilot study assessing out-of-pocket expenses and the insured cancer patient's experience, Oncol. 18 (4) (2013) 381–390.
[24] M.I. Liang, W.K. Huh, Financial toxicity – an overlooked side effect, Gynecol. Oncol. 150 (1) (2018) 3–6.
[25] J.A. de Souza, et al., The development of a financial toxicity patient-reported outcome in cancer: the COST measure, Cancer 120 (20) (2014) 3245–3253.
[26] Real Time Big-Data Report of the Epidemic (疫情实时大数据报告), 2020 [cited 2021; Available from: https://voice.baidu.com/act/newpneumonia/newpneumonia/?from=osari_aladin_banner&city=%E6%B1%9F%E8%8B%8F-%E8%8B%8F%E5%B7%9Ehttps://voice.baidu.com/act/newpneumonia/newpneumonia/?from=osari_aladin_banner&city=%E6%B1%9F%E8%8B%8F-%E8%8B%8F%E5%B7%9E.
[27] Statistics, N.B.o., China Statistical Yearbook 2020, National Bureau of Statistics, Beijing, 2020.
[28] C.J. Duff, et al., The frequency of testing for glycated haemoglobin, HbA1c, is linked to the probability of achieving target levels in patients with suboptimally controlled diabetes mellitus, Clin. Chem. Lab. Med. 57 (2) (2018) 296–304.
[29] G. Sartore, et al., The importance of HbA1c and glucose variability in patients with type 1 and type 2 diabetes: outcome of continuous glucose monitoring (CGM), Acta Diabetol. 49 (1) (2012) 153–160.
[30] K. Baddour, et al., Potential impact of the COVID-19 pandemic on financial toxicity in cancer survivors, Head Neck 42 (6) (2020) 1332–1338.
[31] M.D. Staehler, et al., COVID-19 and Financial Toxicity in Patients with Renal Cell Carcinoma, World J. Urol. (2020) 1–7.
[32] S.B. Solerte, et al., Sitagliptin treatment at the time of hospitalization was associated with reduced mortality in patients with type 2 diabetes and COVID-19: a multicenter, case-control, retrospective, observational study, Diabetes Care 43 (12) (2020) 2999–3006.
[33] S.Y. Patel, et al., Diabetes care and glycemic control during the COVID-19 pandemic in the United States, JAMA Intern. Med. 181 (10) (2021) 1412–1414.