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ORIGINAL ARTICLE

Impact of COVID-19 pandemic on behavioral changes and glycemic control and a survey of telemedicine in patients with diabetes: A multicenter retrospective observational study

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ABSTRACT

Aims/Introduction: To investigate whether the COVID-19 pandemic affected behavioral changes and glycemic control in patients with diabetes and to conduct a survey of telemedicine during the pandemic.

Materials and Methods: In this retrospective study, a total of 2,348 patients were included from 15 medical facilities. Patients were surveyed about their lifestyle changes and attitudes toward telemedicine. Hemoglobin A1c (HbA1c) levels were compared among before (from June 1 to August 31, 2019) and in the first (from June 1 to August 31, 2020) and in the second (from June 1 to August 31, 2021) year of the pandemic. A survey of physician attitudes toward telemedicine was also conducted.

Results: The HbA1c levels were comparable between 2019 (7.27 ± 0.97%), 2020 (7.28 ± 0.92%), and 2021 (7.25 ± 0.94%) without statistical difference between each of those 3 years. Prescriptions for diabetes medications increased during the period. The frequency of eating out was drastically reduced (51.7% in 2019; 30.1% in 2020), and physical activity decreased during the pandemic (48.1% in 2019; 41.4% in 2020; 43.3% in 2021). Both patients and physicians cited increased convenience and reduced risk of infection as their expectations for telemedicine, while the lack of physician–patient interaction and the impossibility of consultation and examination were cited as sources of concern.

Conclusions: Our data suggest that glycemic control did not deteriorate during the COVID-19 pandemic with appropriate intensification of diabetes treatment in patients with diabetes who continued to attend specialized diabetes care facilities, and that patients and physicians shared the same expectations and concerns about telemedicine.

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INTRODUCTION

Since the beginning of the coronavirus disease 2019 (COVID-19) pandemic, people have been forced to change their lifestyles to reduce its spread worldwide. Patients with diabetes who are at a high risk for developing serious illness from COVID-19[1–4] are considered to have received exceptional care during the pandemic, because medical nutrition and exercise therapy which are greatly influenced by lifestyle, are the principles of diabetes treatment. Indeed, people's lifestyles have changed dramatically in the pandemic in the general population[5,6] and in patients with diabetes[7,8], and we have recently reported on the association between the working environment and the worsening glycemic control in patients with diabetes during the COVID-19 pandemic in a single-center, retrospective study[9].

The COVID-19 pandemic has affected the frequency of medical visits and the quality of medical care. Some patients interrupted hospital visits or extended the intervals between visits for fear of COVID-19 infection, presumably leading to a deterioration of diabetes care. We have recently revealed using the Japan Medical Data Center (JMDC) database that patients with diabetes refrained from visiting their hospital/clinic during the first wave of the COVID-19 pandemic in Japan[10]. In such a situation, telemedicine could be an effective solution for diabetes care in the COVID-19 pandemic[11–14]. For example, telemedicine can protect patients with diabetes from COVID-19 infection by reducing hospital visits, and maintain continuity of diabetes care by using web-based and telephone consultation systems with self-monitoring of blood glucose (SMBG) or continuous glucose monitoring (CGM). However, there are several weaknesses and limitations in the current use of telemedicine including individual, professional, organizational, sociopolitical/systemic, technological, and ethical/legal issues[15,16] and surveys of use and attitude of telemedicine in patients with diabetes and their physicians are limited so far.

The aim of this multicenter retrospective observational study was to (1) compare HbA1c levels in patients with diabetes between before and in the first and second year of the pandemic, (2) clarify lifestyle factors associated with glycemic control, and (3) conduct a survey of both patient and physician attitudes toward telemedicine to explore the state of diabetes care in the COVID-19/post COVID-19 era.

MATERIALS AND METHODS

Study design and participants

This is a multicenter retrospective observational study of patients with diabetes who had regularly visited to facilities listed in Table S1, prior to June 1, 2019. The participating facilities are broadly classified into Japan Diabetes compREhensive database project based on an Advanced electronic Medical record System (J-DREAMS)[17] participating facilities and others. The inclusion criteria of this study were as follows: (1) patients who have given written informed consent to participate in the study; (2) patients who were 20 years of age or older at the time that written informed consent was obtained; (3) patients diagnosed with diabetes; (4) patients whose HbA1c levels were able to be confirmed in their medical records from June 1 to August 31 in 2019, 2020, 2021, respectively. Patients who had difficulty in completing the questionnaire were excluded. Finally, a total of 2,348 patients with diabetes were enrolled in this study (Figure 1).

Survey for patient characteristics, laboratory data, and lifestyle habits

Patient characteristics and laboratory data listed in Table S2 were obtained between June 1 and August 31 in 2019, 2020, 2021, respectively. Study participants were given a survey on lifestyle changes during the COVID-19 pandemic (Table S3). The survey included information on working, smoking, alcohol intake, dietary habits, physical activity, household income, and COVID-19 infection. The patients answered the questionnaire from October 8, 2021 to March 28, 2022.

Survey for telemedicine

The patients also completed a survey of telemedicine (Table S4) that included patient expectations and concerns about telemedicine and desired payment costs. The patient's physician also conducted a survey almost similar to the patient's survey (Table S5). The physicians answered the questionnaire from October 8, 2021 to March 28, 2022 as well as the patients.

Outcomes

The primary outcome was the difference in HbA1c levels between before (from June 1, 2019, to August 31, 2019) and in the first (from June 1, 2020, to August 31, 2020) and in the second year (from June 1, 2021, to August 31, 2021) of the COVID-19 pandemic. Difference in weight, body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), plasma glucose, lipid profile [triglycerides, total, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) cholesterol], uric acid, aminotransferase (AST), alanine aminotransferase (ALT), γ-glutamyltranspeptidase (γ-GTP), estimated glomerular filtration rate (eGFR), and urinary albumin-to-creatinine ratio (ACR), hemoglobin, hematocrit was also determined. Body weight over 500 kg and blood pressure over 500 mmHg or less than 20 mmHg were considered as outliers and therefore excluded from the analysis.

Statistical analysis

Patient characteristics and laboratory data were described. Analysis of variance (ANOVA) with repeated measures and Friedman tests were used to analyze differences in these data among 2019 (from June 1, 2019, to August 31, 2019), 2020 (from June 1, 2020, to August 31, 2020), and 2021 (from June 1, 2021, to August 31, 2021). Two measurements in 2019, 2020, and 2021 were compared by paired *t*-tests and Wilcoxon signed-rank tests. Only patients with measurements in the 3 years were included in the analysis. Changes in lifestyles and their situations were also described and compared by Cochran's Q tests,

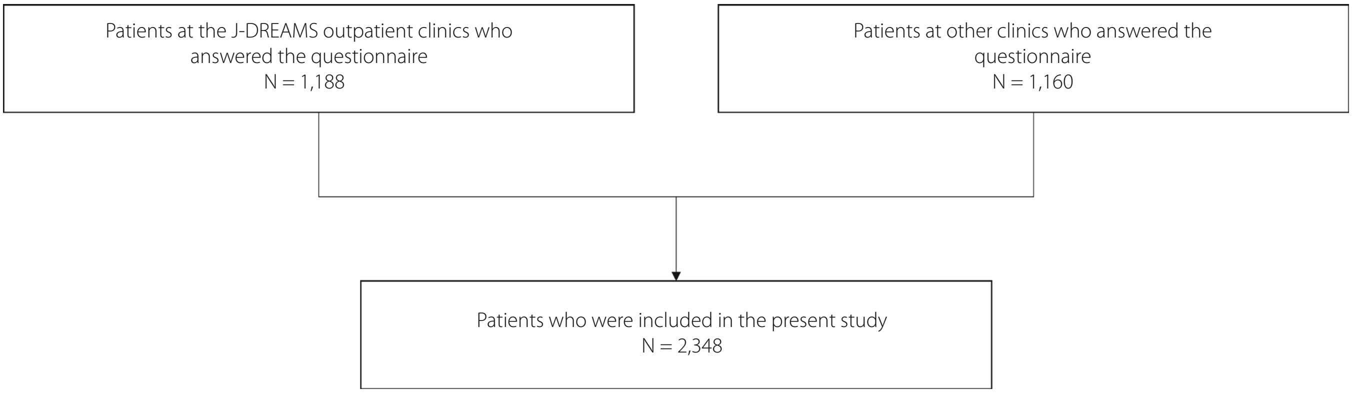

Figure 1 | Flowchart of study patients.

McNemar tests, exact McNemar tests, Friedman tests, and Wilcoxon signed-rank tests. Multiple comparison was performed with the Bonferroni correction. The proportion of preferred type, visit-interval, costs of telemedicine in the patients and the physicians were described and compared using Fisher's exact test or Chi-squared test. Statistical analyses were performed using Stata 17.2 (StataCorp, College Station, TX, USA). A value of $P < 0.05$ was considered statistically significant.

RESULTS

A total of 2,348 participants (57.0% male; 59 ± 13 years old; 18.0% type 1 diabetes) were included. 2.2% and 2.9% of the patients self-reported being infected with the COVID-19 in 2020 and 2021, respectively. As shown in Table 1, almost half of the patients were obese (mean BMI was 25.2 kg/m^2), HbA1c levels (mean ± SD) were 7.27 ± 0.97% (55.9 ± 10.6 mmol/mol), blood pressure, and lipid and urine metabolism were well controlled, and urine protein was negative in more than two-thirds of patients in 2019. Figure 2 shows the change in HbA1c levels during the pandemic. The HbA1c (mean ± SD) levels were almost comparable between before and in the first and second year of the pandemic [7.27 ± 0.97% (55.9 ± 10.6 mmol/mol) in 2019; 7.28 ± 0.92% (56.1 ± 10.2 mmol/mol) in 2020; 7.25 ± 0.94% (55.7 ± 10.2 mmol/mol) in 2021, respectively] in the whole population (Figure 2a); the difference in HbA1c among the 3 years did not reach statistical significance. The results were unchanged when patients were divided into two groups according to age (under 65 years old vs 65 years of age or older, Figure 2b), facility demographics (J-DREAMS participating facilities vs others, Figure 2c), or diabetes type (Type 1 diabetes vs others, Figure 2d).

Table 1 shows the patient characteristics and laboratory data before and during the pandemic. Although weight and BMI were significantly decreased during the pandemic, the changes were minimal. There was a significant difference between DBP in 2019 and 2021, hemoglobin and hematocrit in 2019 and 2020, and HDL cholesterol in 2020 and 2021, but the difference was very small. A slight decrease in LDL cholesterol was also observed during the pandemic. Estimated GFR levels were gradually decreased from 2019 to 2021, while no clinically meaningful differences in urinary ACR were observed during the pandemic. The proportion of patients with urinary glucose (3+) and (4+) was increased 36.9–43.3% and that of patients without urinary protein was increased from 67.3% to 73.0%. Table S6 shows medications for diabetes, hypertension, dyslipidemia, and hyperuricemia. Among agents for diabetes, SGLT2 inhibitors and GLP-1 receptor agonists exhibited an increase of more than 5% in absolute value during the pandemic.

Regarding the working environment and lifestyle habits (Table 2), the proportion of patients employed was gradually decreased, while the percentage of those teleworking increased sharply, more than tripling in the COVID-19 pandemic. The proportion of current smokers was gradually and significantly decreased during the pandemic and patients with a drinking habit was slightly decreased from 2019 to 2020 and unchanged from 2020 to 2021. The percentages of patients eating snacks and eating prepared foods at least once a week remained unchanged, while that of patients eating out at least once a week was drastically and significantly decreased from 2019 to 2020 and recovered slightly but significantly from 2020 to 2021. The percentage of patients with exercise habits decreased from 2019 to 2020 and increased slightly in 2021. Approximately 14% of the participants had a dog during the pandemic. The proportion of patients with high household income was decreased during the pandemic. As shown in Table 2, lifestyle changes were larger in the first year of the COVID-19 pandemic (2020), with a slight rebound in the second year (2021) for some lifestyle habits.

Among 2,346 patients who answered the questionnaire for telemedicine, only 2.8% reported having received telemedicine. Of these patients, 64.6% indicated that they would like to keep using telemedicine. On the other hand, 25.0% of patients who had never received online care indicated that they would like to use telemedicine in the future. Among 83 physicians who

Table 1 | Clinical characteristics and laboratory data

	n	June to August, 2019		June to August, 2020		June to August, 2021		Comparison among 2019, 2020, and 2021	June to August, 2019 vs June to August, 2020	June to August, 2019 vs June to August, 2021	June to August, 2020 vs June to August, 2021
		Mean	SD	Mean	SD	Mean	SD	*P* value	*P* value	*P* value	*P* value
Age (years)	2,348	60.0	13.4								
Sex (% male)	2,348	57.4%									
Type of diabetes (Type1/Type2/Other/ Gestational/unknown)	2,348	423/ 1,839/ 67/1/ 18									
Weight(kg)	1,929	67.3	14.8	67.2	14.8	66.9	14.7	<0.001[†]	1.00[‡]	<0.001[‡]	<0.001[‡]
Body mass index (kg/ m^2)	1,836	25.2	4.6	25.2	4.6	25.1	4.5	<0.001[†]	1.00[‡]	<0.001[‡]	<0.001[‡]
SBP (mmHg)	1,892	125.8	14.7	126.3	15.0	125.8	15.1	0.18[†]	0.30[‡]	1.00[‡]	0.30[‡]
DBP (mmHg)	1,892	71.9	11.4	71.5	11.3	71.3	11.1	0.008[†]	0.17[‡]	0.009[‡]	0.62[‡]
Hemoglobin (g/L)	1,930	14.0	1.6	14.0	1.6	14.0	1.7	0.05[†]	0.05[‡]	0.34[‡]	1.00[‡]
Hematocrit (%)	1,945	41.9	4.6	42.1	4.7	42.0	4.9	0.02[†]	0.02[‡]	0.19[‡]	1.00[‡]
AST (U/L)	2,233	24.3	14.1	24.4	14.0	23.8	12.2	0.12[†]	1.00[‡]	0.27[‡]	0.12[‡]
ALT (U/L)	2,241	25.8	21.2	26.2	22.8	25.5	19.3	0.17[†]	0.87[‡]	1.00[‡]	0.14[‡]
Glucose (mmol/L)	2,343	8.49	2.97	8.58	2.96	8.46	2.95	0.23[†]	0.68[‡]	1.00[‡]	0.27[‡]
HbA1c (%)	2,348	7.27	0.97	7.28	0.92	7.25	0.94	0.11[†]	1.00[‡]	0.88[‡]	0.06[‡]
HbA1c (mmol/mol)	2,348	55.9	10.6	56.1	10.2	55.7	10.2				
Triglycerides (mmol/L)	2,212	1.70	1.31	1.70	1.31	1.67	1.47	0.57[†]	1.00[‡]	1.00[‡]	1.00[‡]
Total cholesterol (mmol/mol)	1,653	2.61	0.72	2.58	0.72	2.56	0.71	<0.001[†]	0.04[‡]	<0.001[‡]	0.12[‡]
HDL cholesterol (mmol/mol)	2,204	1.50	0.47	1.51	0.45	1.50	0.45	0.08[†]	0.33[‡]	1.00[‡]	0.05[‡]
LDL cholesterol (mmol/ mol)	2,186	2.62	0.73	2.58	0.72	2.56	0.72	<0.001[†]	0.02[‡]	<0.001[‡]	0.27[‡]
Uric acid (μmol/L)	2,002	307.3	79.3	310.1	97.0	308.5	80.9	0.19[†]	0.26[‡]	1.00[‡]	1.00[‡]
eGFR (mL/min/1.73 m^2)	2,244	73.0	21.37	71.3	21.70	70.3	21.76	<0.001[†]	<0.001[‡]	<0.001[‡]	<0.001[‡]
Log_{10} (urinary ACR (mg/g))	1,512	1.15	0.32	1.16	0.34	1.15	0.36	0.002[†]	0.15[‡]	0.003[‡]	0.25[‡]
Urinary protein (*n*, %)	2,072										
(–)	1,395	67.3%	1,461	70.5%	1,512	73.0%		<0.001[§]	0.38[¶]	<0.001[¶]	0.02[¶]
(±)	415	20.0%	334	16.1%	320	15.4%					
(+)	163	7.9%	166	8.0%	135	6.5%					
(2+)	72	3.5%	81	3.9%	75	3.6%					
(3+)	24	1.2%	25	1.2%	29	1.4%					
(4+)	3	0.1%	5	0.2%	1	0.1%					
Urinary glucose (*n*, %)	1,906										
(–)	952	50.0%	883	46.3%	824	43.2%		<0.001[§]	0.07[¶]	<0.001[¶]	0.02[¶]
(±)	90	4.7%	75	3.9%	85	4.5%					
(+)	93	4.9%	98	5.1%	84	4.4%					
(2+)	69	3.6%	82	4.3%	89	4.7%					
(3+)	474	24.9%	534	28.0%	581	30.5%					
(4+)	228	12.0%	234	12.3%	243	12.8%					
Urinary blood (*n*, %)	2,072										
(–)	1,687	81.4%	1,671	80.7%	1,649	79.6%		0.58[§]	1.00[¶]	1.00[¶]	1.00[¶]
(±)	179	8.6%	196	9.5%	226	10.9%					
(+)	122	5.9%	131	6.3%	114	5.5%					
(2+)	59	2.9%	50	2.4%	68	3.3%					
(3+)	25	1.2%	24	1.2%	15	0.7%					

Table 1. (*Continued*)

	n	June to August, 2019		June to August, 2020		June to August, 2021		Comparison among 2019, 2020, and 2021	June to August, 2019 vs June to August, 2020	June to August, 2019 vs June to August, 2021	June to August, 2020 vs June to August, 2021
		Mean	SD	Mean	SD	Mean	SD	*P* value	*P* value	*P* value	*P* value
Urinary ketone (*n*, %)	1,870										
(−)	1,779	95.1%	1,746	93.4%	1,750	93.6%		0.02§	0.03¶	0.14¶	0.97¶
(+−)	33	1.8%	48	2.6%	62	3.3%					
(+)	48	2.6%	53	2.8%	42	2.3%					
(2+)	9	0.5%	17	0.9%	12	0.6%					
(3+)	1	0.1%	6	0.3%	4	0.2%					

†ANOVA tests with repeated measures. ‡Paired *t*-tests with Bonferroni correction. §Friedman tests. ¶Wilcoxon signed-rank tests with Bonferroni correction. ACR, albumin-to-creatinine ratio; ALT, alanine aminotransferase; AST, aspartate aminotransferase; DBP, diastolic blood pressure; FY, fiscal year; GFR, glomerular filtration rate; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SBP, systolic blood pressure.

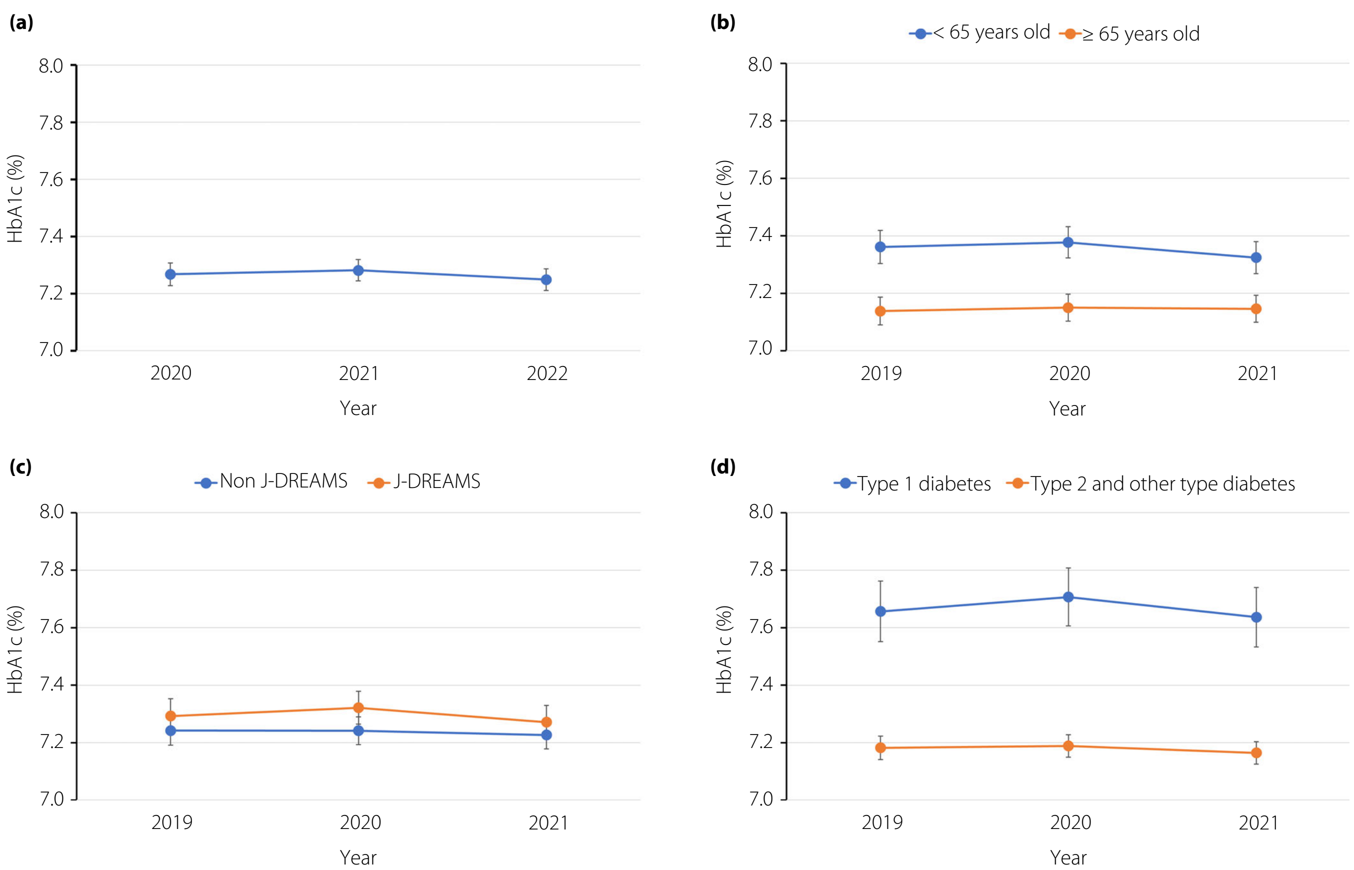

Figure 2 | HbA1c levels (mean ± SEM %) before (in 2019) and during (in 2020 and 2021) the COVID-19 pandemic in (a) the whole population, according to (b) age (≥65 years old or <65 years old), (c) type of facility (facilities participating in the J-DREAMS or others), (d) type of diabetes (type 1 diabetes or others).

answered the questionnaire for telemedicine, 49.4% reported performing telemedicine. Of these physicians, 37.3% desired to keep using telemedicine. 33.7% of physicians who had never performed telemedicine reported that they would like to use telemedicine in the future. Figure 3a shows the patient's expectations and concerns regarding telemedicine. Reduced time for

Table 2 | Lifestyle changes during the COVID-19 pandemic

	n	Period 1 Before the pandemic Percent	Period 2 First year of the pandemic Percent	Period 3 Second year of the pandemic Percent	Comparison among 3 periods *P* value	Period 1 vs Period 2 *P* value	Period 1 vs Period 2 *P* value	Period 2 vs Period 3 *P* value
Working environment	2,273							
Employed (%)	2,273	62.6%	60.2%	58.9%	<0.001†	<0.001‡	<0.001‡	0.006‡
Desk work	2,273	26.8%	26.3%	25.8%	0.05†	0.59‡	0.10‡	0.47‡
Work with a lot of physical activity	2,273	34.2%	31.6%	31.2%	<0.001†	<0.001‡	<0.001‡	0.75‡
Telework	2,273	1.9%	7.2%	7.0%	<0.001†	<0.001‡	<0.001‡	1.00‡
Non-employed (%)	2,273	37.4%	39.8%	41.1%	<0.001†	<0.001‡	<0.001‡	0.006‡
After retirement	2,273	17.5%	19.0%	19.8%	<0.001†	<0.001‡	<0.001‡	0.01‡
Student	2,273	0.9%	0.9%	0.7%	0.007†	1.00§	0.19§	0.19§
Housewife	2,273	14.8%	14.8%	14.8%	1†	1.00§	1.00§	1.00§
Out of work	2,273	1.5%	1.9%	2.1%	0.01†	0.35§	0.04§	0.80§
Unemployed	2,273	0.9%	1.0%	1.2%	0.05†	1.00§	0.23§	0.54§
Smoking (%)	2,289	18.0%	17.2%	16.8%	<0.001†	<0.001‡	<0.001‡	0.08‡
Drinking (%)	2,015	42.0%	39.6%	39.4%	<0.001†	<0.001‡	<0.001‡	1.00‡
Snacking at least once a week (%)	2,169	70.4%	70.0%	70.0%	0.61†	1.00‡	1.00‡	1.00‡
Eating prepared foods once a week (%)	2,097	39.1%	39.1%	39.7%	0.34†	1.00‡	0.77‡	0.21‡
Eating out at least once a week (%)	2,131	51.7%	30.1%	33.5%	<0.001†	<0.001‡	<0.001‡	<0.001‡
Physical activity (%)	2,191	48.1%	41.4%	43.3%	<0.001†	<0.001‡	<0.001‡	<0.001‡
Having a dog (%)	2,142	16.2%	14.2%	13.8%	<0.001†	<0.001‡	<0.001‡	0.18‡
Monthly household income (yen)	2,010							
Less than 200,000 (%)	2,010	23.2%	24.3%	24.7%	<0.001¶	<0.001††	<0.001††	<0.001††
200,000 or more but less than 400,000 (%)	2,010	40.3%	41.1%	41.7%				
400,000 or more but less than 600,000 (%)	2,010	19.0%	17.8%	17.2%				
600,000 or more but less than 800,000 (%)	2,010	6.4%	5.9%	5.6%				
800,000 or more (%)	2,010	9.5%	9.1%	8.9%				
A welfare recipient (%)	2,010	1.7%	1.7%	1.8%				

Before the pandemic; until December 2019, First year of the pandemic; between June and August, 2020, Second year of the pandemic; between January, 2021 and the date of survey (October, 2021 to March 2022). †Cochran's Q tests. ‡McNemar tests with Bonferroni correction. §Exact McNemar tests with Bonferroni correction. ¶Friedman tests. ††Wilcoxon signed-rank tests with Bonferroni correction.

medical care (increased convenience) was the most common factor expected by patients, followed by reduced risk for infection, and receiving medications at home. The most frequent cause for concern was the lack of access to laboratory tests and medical examinations and the second was a lack of interaction with the physician. Similar results to the patients' expectations and concerns were obtained from the survey of physicians (Figure 3b). The patients and physicians were almost similar in their preferred format of telemedicine and desired intervals between telemedicine visits, i.e., web-based care was most frequently desired, and 1 month was the most preferred interval between visits (Figure S1a,b). Regarding desired costs for telemedicine, the patients' preferred reimbursement per month was significantly lower than the physicians' preferred reimbursement per month (Figure S1c). The desired cost for measuring blood glucose was higher, and those for measuring HbA1c and CGM were lower in the patients than those in the physicians (Figure S1D–F). Regarding the preference for online medical care for complications, patients and physicians, respectively, preferred retinopathy 50.2%, 60.5%, nephropathy 53.5%, 82.9%.

DISCUSSION

In this multicenter, retrospective observational study, we revealed that (1) HbA1c levels were almost comparable between before and in the first and second year of the pandemic in patients with diabetes; (2) the proportions of both current

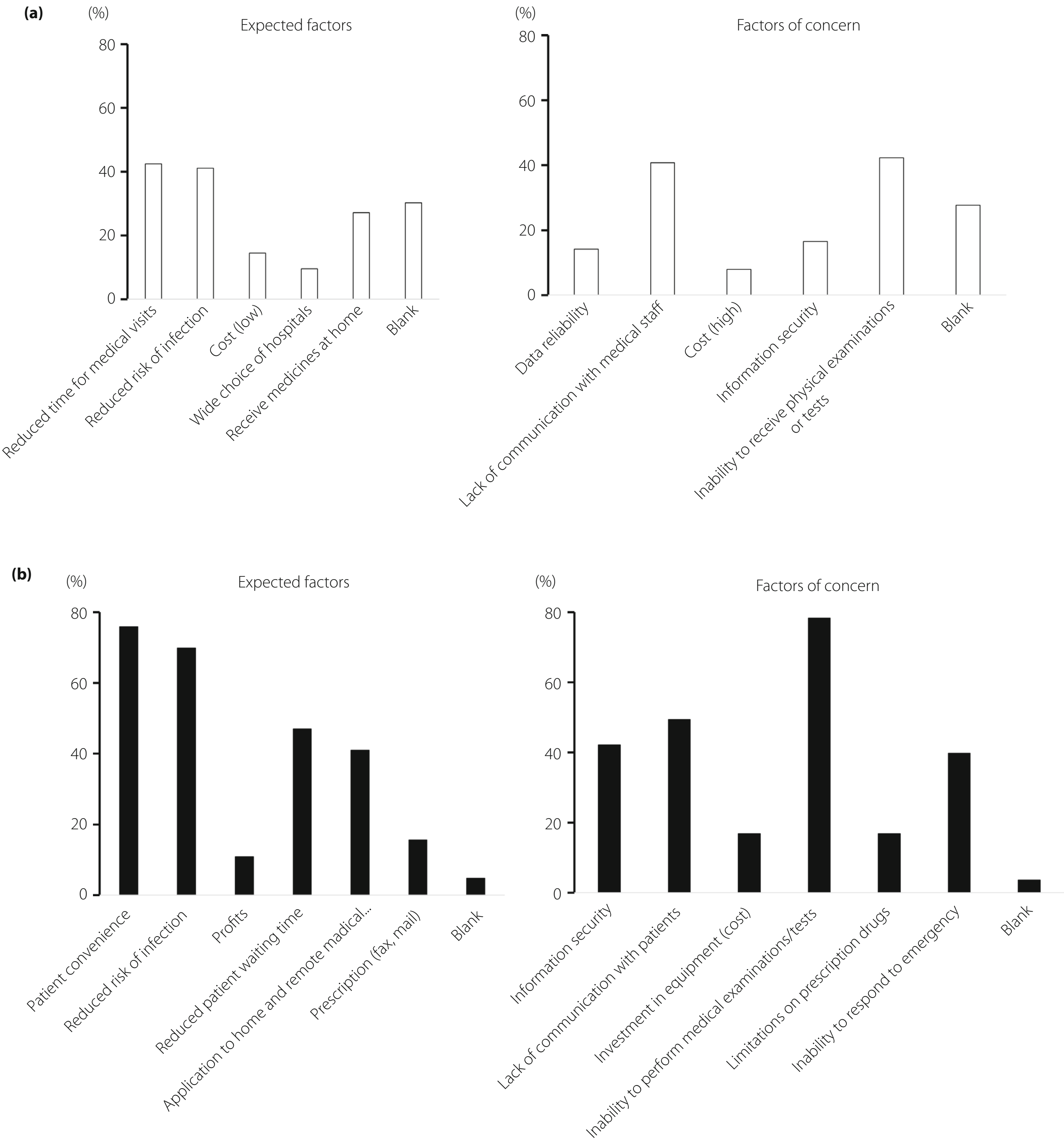

Figure 3 | Expectations and concerns regarding telemedicine in patients with diabetes (a) and their physicians (b).

smokers and drinkers were decreased, eating out was drastically decreased in the first year of the pandemic, and physical activity was gradually decreased from the beginning to the second year of the pandemic; (3) both patients and physicians cited increased convenience and a reduced risk of infection as their expectations for telemedicine, while a lack of physician–patient interaction and the impossibility of consultation and examination were cited as sources of concern.

Although it is inconclusive to date whether glycemic control would worsen during the COVID-19 pandemic in patients with diabetes in Japan[9,18–27], it was important to keep adequate glycemic control during the pandemic in patients with diabetes to prevent severe conditions in case they were infected with the COVID-19. Our data confirmed that the overall glycemic control of patients with diabetes did not deteriorate in the pandemic, independent of age, type of diabetes, and facility demographics. The result should be taken into account fully for the characteristics of this study. In this study, the participants were recruited from specialized diabetes care facilities and they regularly visited their clinic/hospital before and during the pandemic. As shown in Table S6, their diabetes treatment was intensified during the pandemic, thus worsening of glycemic control could have been prevented. One reason for the differences in the impact of the COVID-19 pandemic on glycemic control between studies may be the difference in the observational period. Several studies[18,20,23–26] compared HbA1c in the several months before and after the pandemic, presumably focusing on the possibility of rapid behavioral changes and restrictions to healthcare access in the early stages of the pandemic. In contrast, others[9,19,21,23,27] including this study, considered seasonal variations in HbA1c and evaluated changes in HbA1c in the year before and after the pandemic.

Regarding lifestyle, we found in this study that the COVID-19 pandemic markedly changed patients' working environment (increase in telework), eating and exercise habits (decreased physical activity and decline in eating out); these were consistent with the result of a previous report from Japan[26]. The Ministry of Labour and Welfare of Japan has compiled the results of several web-based surveys conducted in Japan[28]. Among 83,216 men and women aged 20–79 (subjects were selected according to the national population distribution), the proportion of people whose alcohol consumption was increased/decreased was small and almost comparable (4.8% and 5.9%). The proportion of people who answered that physical activity was decreased was a bit higher than those in whom it was increased (6.5% vs 3.9%). Among 6,000 people who answered a questionnaire regarding dietary habits, 20.3% reported that their current diet was healthier than that before the pandemic, as it was more unhealthy in 8.2%. In contrast, our data revealed that the percentage of patients with exercise habits decreased by 7% from 2019 to 2020 and that of smoking and drinking were almost unchanged during the pandemic, suggesting that people with diabetes at higher risk for worsening COVID-19 may have been less physically active than the general population, as they were less likely to go out due to fear of infection. In our previous study in a single institution[9], some lifestyle changes were associated with the change in HbA1c levels. In terms of the timing of questionnaire responses and the timing of HbA1c acquisition, this study was unable to determine the relationship between lifestyle changes and changes in glycemic control. In the COVID-19/post COVID-19 era, it is desirable to conduct research to examine how to intervene in the lifestyle of patients with diabetes to ensure appropriate diabetes management.

In Japan, the government policy recently proposed the use of telemedicine[29,30], and it is thought to be a form of large-scale social demonstration experiment under a time-limited relaxation measure. The social structure that will become the new normal is being explored. It is highly likely that Information and Communication Technology (ICT) in medicine, including the permanent introduction of telemedicine, will advance in the clinical practice setting. Telemedicine can cover a large portion of the routine medical examination, including interviewing, coaching and management, and prescribing. In the case of patients with chronic diseases such as diabetes, adherence to treatment, and medication adherence are key, and telemedicine is effective in keeping these adherences high and reducing the cost of hospital visits. In addition to the potential of telemedicine to reduce the risk for infections by avoiding hospital visits, telemedicine has been reported to improve glycemic control in patients with diabetes[31–34]. In addition, telemedicine could reduce the prevalence of positive screening for mental health disorders and diabetes-related emotional distress in patients with type 2 diabetes[35]. Therefore, telemedicine has been gaining attention as a style of medical care in diabetes during the COVID-19 pandemic. Although we were unable to examine in this study whether telemedicine could improve glycemic control during the pandemic due to the small number of cases who used telemedicine (2.8%), a recent study from Japan revealed that the use of telemedicine was associated with an improvement in HbA1c in patients with diabetes with pre-pandemic HbA1c levels of ≥7.0%[25]. In this study, both patients with diabetes and their physicians were found to cite common reasons for their expectations and concerns about telemedicine during the COVID-19 pandemic. These results suggest that in implementing telemedicine, both physicians and patients with diabetes are oriented in the same direction and there are common priorities and issues that need to be resolved in order to realize telemedicine in diabetes care. In telemedicine for diabetes care, self-monitoring blood glucose (SMBG) and continuous glucose monitoring (CGM) are important for capturing glycemic control, but in Japan, insurance coverage is limited to users of injectable medications such as insulin. It was recently reported that telemedicine significantly improved glycemic control during the COVID-19 pandemic in 2020, but clinic visits improved HbA1c significantly more[27]. The result may imply the need for more detailed online medical care and further dissemination of home blood glucose monitoring will be necessary to expand telemedicine.

More than half of both patients and their physicians preferred the web as a form of telemedicine (Figure S1a). This may have been due to the reassurance of being able to see the patient/physician's face and the ability to utilize web-based patient health information. Regarding the interval between visits and the cost of telemedicine (Figure S1b–f), patients preferred longer and cheaper visits, indicating a gap between physicians and patients. Finally, more than half of both physicians and patients desired the use of telemedicine for the management of diabetic retinopathy and nephropathy. Digital health technology to examine diabetic retinopathy has recently developed and the diagnostic accuracy of retinopathy using a smartphone camera for digital retinal imaging was generally high, especially in the case of proliferative diabetic retinopathy[36]. The collection of urine and testing at home for assessing proteinuria/albuminuria is non-invasive, simple, and cheap, thus, hurdles to its practical application are considered low. It is desirable for the better management of diabetic vascular complications that these tests in telemedicine will be covered by insurance during the COVID-19 pandemic and in the post-COVID 19 era.

The strengths of this study are that more than 2000 cases were enrolled from multiple medical facilities, corroborating the results of our smaller previous study and a recent meta-analysis[1,9,29] and this is the first to clarify the fact that patients and physicians shared the same expectations and concerns about telemedicine. Some limitations of this study also need to be discussed. First, as this study was conducted only in Japan, it is difficult to generalize the results to other racial and ethnic groups. Second, it is impossible to investigate the influence of patients who had dropped-out of regular medical visits on glycemic control as they were not included in this study (their HbA1c levels were unavailable); therefore, selection bias could exist. Third, the questionnaires used in this study provided only qualitative data for information related to diet and exercise. Thus, it is unclear whether blood glucose was well controlled by appropriate medical nutrition and exercise therapies. Finally, the patients in this study were visiting clinics/hospitals specializing in diabetes care, therefore, it is unclear whether the results obtained in this study could apply to patients attending non-specialized facilities.

In conclusion, we confirmed that overall glycemic control did not worsen during the COVID-19 pandemic with appropriate intensification of diabetes treatment in patients with diabetes who continued to attend specialized diabetes care facilities. As patients and physicians shared the same expectations and concerns about telemedicine, the establishment of appropriate telemedicine for diabetes in the with- and post-COVID-19 era is desirable.

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DISCLOSURE

The authors declare no conflict of interest.
Approval of the research protocol: This study was approved by the Institutional Review Board for Clinical Research of the National Center for Global Health and Medicine (approval number, NCGM-S-004287-03; approval date, November 05, 2021).
Informed consent: Written informed consent was obtained from all patients.
Registry and the registration no. of the study/trial: N/A.
Animal studies: N/A.

DATA AVAILABILITY

Data are available from the authors upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1 | Preferred form (a), interval between visits (b), total medical cost per month of telemedicine (c), cost for at home blood glucose measurement (d), HbA1c measurement (e), and continuous glucose monitoring (f).

Table S1 | Participating facilities of the study

Table S2 | Schedule of data collection

Table S3 | A survey of lifestyle changes during the COVID-19 pandemic

Table S4 | A survey of telemedicine for patients with diabetes

Table S5 | A survey of telemedicine for diabetologists

Table S6 | Medications for diabetes, hypertension, dyslipidemia, and hyperuricemia