Over- and Under-Provision of Diabetes Screening: Making More Efficient Use of Healthcare Resources*

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Abstract

National medical care expenditure in Japan exceeded 43 trillion yen in FY2018, with over 1.2 trillion yen of this total being spent on diabetes care. The sales of diabetes drugs continue to increase by several percent every year, and in FY2020 were second only to anti-cancer drugs. Even with such huge healthcare and drug expenditure on the treatment of diabetes, the number of patients undergoing dialysis due to diabetes continues to increase, and the number of chronic dialysis patients in Japan per capita was shown to be by far the largest in an international comparison. At the end of 2020, there were 275.4 dialysis patients per 100,000 people in Japan, of which 39.5% of chronic dialysis patients had diabetic nephropathy, in which the kidneys are damaged due to diabetes.

A previous analysis of the length of hospitalization for diabetes patients in Japan showed that the average number of days spent in hospital was extremely long, with a cost-benefit analysis indicating that this is difficult to justify. The results of the data analysis carried out in this paper suggest that many people suffering from severe diabetes may not actually be receiving treatment. In contrast with the major diabetes screening programs overseas, it is clear that the Japanese program (1) does not evaluate the risk of developing diabetes, although it does include an age limit; (2) carries out annual screening regardless of the risk and/or blood sugar level; and (3) is not updated by the best available evidence from the latest clinical research.

Many stakeholders, including local governments, health insurance associations, and the Ministry of Health, Labour and Welfare, have already pointed out the importance of preventing diabetes aggravation. In this paper, we explore the reasons why Japan's efforts to encourage people at high risk to receive preventive medical care are failing, and propose

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necessary measures to achieve organic cooperation between screening programs and healthcare provision.

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I. Introduction

According to the Ministry of Health, Labour and Welfare (2020), Japan's total national medical expenditure in fiscal year (FY) 2018 was 43.39 trillion Japanese yen, 16.55 trillion yen (38.1%) of which was publicly funded (10.96 trillion yen from central government and 5.59 trillion yen from local government). Public insurance premiums accounted for 19.52 trillion yen (49.4%) of the total expenditure (9.20 trillion yen paid by employers and 12.3 trillion yen paid by insured persons), while direct expenditure by patients was only 5.13 trillion yen (11.8%). Japan has adopted a universal health insurance system whereby every resident is required to join some type of public medical insurance scheme, and this system has provided people with many benefits. However, owing to the aging population and advances in medical technology, total medical expenditure is expected to increase even further. If this situation continues, it is predicted that it will become near impossible to sustain the current health insurance system in the long term. Indeed, a number of privately established health insurance societies have already been forced into closure because of the financial burdens they were under. To avoid the collapse of the medical insurance system, keeping medical expenditure under control by making more efficient use of medical resources is an urgent political issue.

In this study, we first analyze the length of hospital stay (LOS) for patients in Japan with type 2 diabetes mellitus (hereafter, diabetes). Such patients account for more than 90% of all patients with diabetes in Japan. The diagnostic indicator for diabetes is insufficient insulin either resulting from reduced insulin secretion or from a patient being unable to use the secreted insulin effectively; however, the causes of the disease are still unknown. Diabetes is known as one of the most serious 'lifestyle diseases.' According to the World Health Organization (WHO, 2021), 8.5% of adults aged 18 years or over had diabetes in 2014. The WHO estimated that there were 1.5 million deaths directly caused by diabetes in 2019. Furthermore, when deaths due to cardiovascular disease, chronic kidney disease, and tuberculosis caused by high glucose levels are included, it is estimated that 2.2 million deaths were due to high blood glucose (BG) in 2012, the latest year for which data are available.

In 2018, medical expenditure on diabetes in Japan was 1.21 trillion yen, putting it in a similar league to expenditure on hypertension, which totaled 1.80 trillion yen (Ministry of Health, Labour and Welfare, 2020). As shown in Table 1, the sales revenue from diabetes medicines in FY 2011 was ranked in fifth place after renin-angiotensin-type medicines (an-

Table 1. Change in sales revenue from medicines in Japan, by class of drug (unit: million yen)

Rank (FY2020)	Class of drug	FY2011	FY2020	Change on previous year
1	Antitumor agents	631,510	1,518,683	5.1%
2	Antidiabetic agents	392,479	610,563	4.4%
3	Immunosuppressive agents		478,616	3.4%
4	Antithrombotic agents	365,982	419,930	−5.1%
5	Agents for ophthalmic use		359,590	1.3%
6	Antacids / flatulence- and ulcer-treating agents	437,158	347,155	−1.4%
7	Agents acting on renin-angiotensin system*	657,754	293,419	−6.0%
8	Agents acting on central nervous system (other)	275,767	289,765	−6.1%
9	Lipid regulators and antiatherosclerotic agents	447,558	272,177	−11.0%
10	Asthma and chronic obstructive pulmonary disease-treating agents	303,241	263,793	−12.5%
Total sales revenue		9,481,578	10,347,565	−2.7%

Note: * Anti-hypertensive drugs such as ACEIs and ARBs
Source: IQVIA pharmaceutical market statistics (IQVIA, 2021; Ii, 2015)

ti-hypertensive drugs such as ACEIs and ARBs), antitumor agents, lipid regulators and anti-atherosclerotic agents, and flatulence- and ulcer-treating agents. However, sales revenue from diabetes medicines has been increasing by a few percentage points per year, and in FY 2020, antidiabetic medicine revenue was second only to that of antitumor agents. The rapid revenue growth seen among antitumor agents (5.1% on the previous year) might be expected, owing to the appearance of some expensive drugs on the market that were themselves the subject of much controversy and public debate. However, it may come as a surprise to many people to learn that sales revenue for diabetes medicines has grown by more than 4% in the same period.

Not only is diabetes medically costly, but it can also cause more serious diseases. For example, the International Diabetes Foundation (IDF, 2020) noted that one of the biggest problems of diabetes is that it can lead to serious complications over time, such as heart, brain, eye, kidney, nerve, skin, and foot problems. Consistently high BG levels can cause serious cardiovascular, eye, kidney, nerve, and teeth diseases and increase susceptibility to infections. Furthermore, the IDF also pointed out that diabetes is the leading cause of cardiovascular disease, blindness, kidney disease, and lower-limb amputation in most high-income countries. WHO (2020) stated that patients with hypertension and diabetes are more vulnerable not only to non-communicable diseases but also to COVID-19, the severe acute respiratory syndrome caused by novel coronavirus (SARS-CoV-2), and have a higher risk of death.

Despite such high medical and pharmaceutical expenditure, the number of dialysis patients in Japan has been increasing. The number of dialysis patients in Japan as a proportion of the population is much larger than other countries. According to Hanafusa et al. (2021), the proportion of dialysis patients per 100,000 people was 275.4 at the end of 2020, and 39.5% of chronic dialysis patients had diabetic nephropathy (i.e., kidney failure caused by diabetes).

However, type 2 diabetes, the most prevalent type of diabetes, can be prevented by lifestyle improvements. The American Diabetes Association (ADA, 2021a) has noted that prevention and improvement of diabetes are possible through targeted lifestyle changes, such as better dietary and exercise habits.

According to the General Patient Survey conducted by the Ministry of Health, Labour and Welfare (2021b), there were 18,900 diabetes inpatients and 224,000 diabetes outpatients on survey day was held in 2017. This corresponds to 15 inpatients and 177 outpatients (male, 203; female, 152) per 100,000 population, respectively. The average LOS in hospital was 33.3 days overall, with averages of 16.3 days for patients aged 35–64 years, 45.4 days for patients aged 65 or over, and 62.1 days for patients aged 75 or over, indicating that older patients stayed in hospital for longer periods (Ministry of Health, Labour and Welfare, 2018). Meanwhile, there were 7,125 deaths due to diabetes in men (gross death rate: 11.7 per 100,000) and 5,202 in women (9.6 per 100,000) (Ministry of Health, Labour and Welfare 2020c). The Ministry of Health, Labour and Welfare (2019c) also reported that 14.5% of the Japanese population were strongly suspected of having diabetes in 2019, among whom 55.6% were taking medicines controlling BG levels (including insulin injections). A further 12.7% of people were considered to possibly have diabetes. However, this survey had several issues, including its small sample size (2,412 people) and the fact that the effects of age, sex, and other health factors were not considered.

In this paper, on the basis of analysis from our previous studies, we first evaluate the average LOS (ALOS) for patients with diabetes. Then, using the JMDC Claims Database (JMDC, 2021), we newly analyze the diabetes situation in Japan and the problems relating to its treatment. The database contains information concerning health checkups, medical payments, and treatments, which was collected from a variety of health insurance societies across Japan. In our analysis, the JMCD data used comprises 13,157,681 health checkups undertaken by 3,233,271 people in Japan.

II. Analysis of the length of hospital stay and medical fees for diabetes in Japan

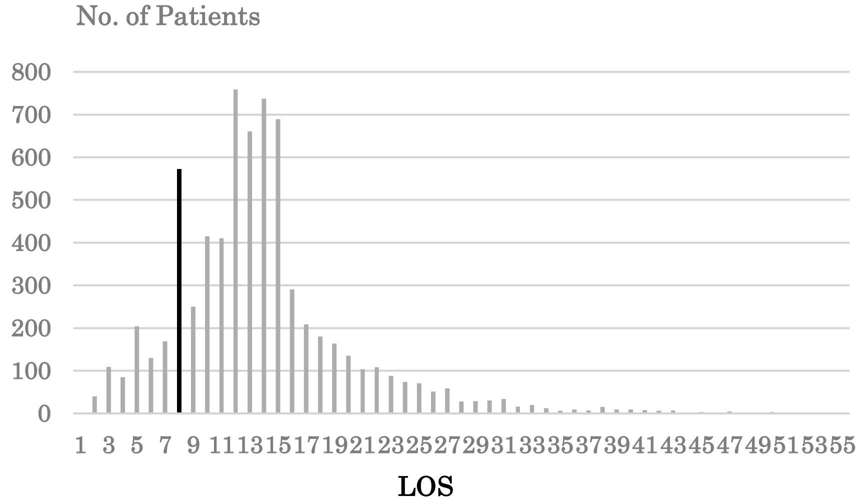
II-1. Analysis of patients undergoing educational hospitalization for diabetes

One of the most noticeable characteristics of the Japanese medical system is the very long LOS for patients with diabetes. In this section, we analyze LOS of diabetes patients who joined educational programs to improve their lifestyles through dietetic treatments and kinesitherapy rather than direct medical treatments (hereafter, educational hospitalization). In 2003, Japan introduced a medical payment methodology based on diagnosis procedure combination (DPC), which is now referred to as the DPC/per diem payment system (PDPS). (Hereafter, we refer to DPC/PDPS as the DPC system and hospitals that use the DPC system as DPC hospitals.) Nawata and Kawabuchi (2015) analyzed LOS of diabetes patients undergoing educational hospitalization. The dataset was collected by the Department of Health Care Economics at the Tokyo Medical and Dental University from over 100 DPC hospitals. The sample period was from July 2008 to March 2012. The original dataset contained 27,861 diabetes patients, and the ALOS was 17.9 days. Excluding the 206 patients for whom medical expenses data were unavailable, the average medical expenditure per hospitalization was 484,858 yen. Among the total of 27,861 diabetes patients, 7,854 were undergoing educational hospitalization, and their ALOS was 14.0 days and average medical expenditure 377,735 yen. In FY 2010, the DPC system was revised. To eliminate the effects of differences in disease categories, we analyzed only patients hospitalized under the DPC code 100070xxxxxx0x (type 2 diabetes without ketoacidosis and collateral diseases). The number of patients undergoing educational hospitalization with DPC code 100070xxxxxx0x was 7,094. We first selected patients without any missing values for the necessary variables and who stayed at hospitals that had at least 10 qualifying patients both before and after the April 2010 revision.

Figure 1 shows the distribution of LOS. It shows a peak in LOS on day eight (one week after hospitalization) and has a heavy right tail. The ALOS of all patients was 13.7 days and the average medical expenditure was 370,336 yen. Figure 2 shows the ALOS and average medical expenditure (per hospitalization) among the hospitals in the dataset. The minimum ALOS was 5.7 days and the maximum was 27.1 days, which corresponds to a difference of 21.4 days and a maximum-to-minimum ratio of 4.7, indicating a very large degree of variation among hospitals. We also evaluated the effects of the DPC/PDPS revision in April 2010, using data for 6,173 patients (who were not missing any values) from 36 hospitals for the explanatory variables.

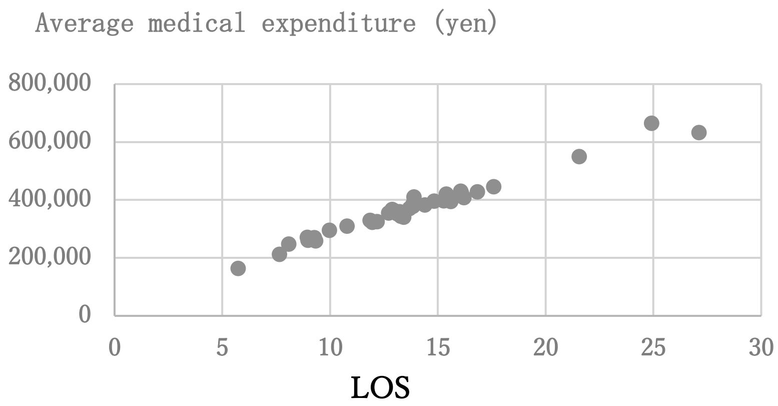
Of course, LOS naturally depends on the patient’s condition. Although the effects on educational hospitalization might be small, hospitals with many patients requiring special care owing to serious health conditions and aging are likely to report prolonged ALOS. Therefore, it is necessary to control for patient characteristics using an econometric model. Because the distribution of LOS has a heavy right tail and includes some patients with exceptionally long LOS, the ordinary least squares (OLS) method may not be suitable for

Figure 1. Distribution of length of stay (LOS) for educational hospitalization



Source: Nawata and Kawabuchi (2015)

Figure 2. Average length of stay (LOS) and average medical expenditure per hospitalization for educational hospitalization



Source: Nawata and Kawabuchi (2015)

analyzing this dataset. Therefore, the following Box-Cox transformation (BC) model was used for the analysis:

$$z_t = \begin{cases} \dfrac{y_t^{\lambda} - 1}{\lambda}, \text{ if } \lambda \neq 0, \\ \log(y_t), \text{ if } \lambda = 0, \end{cases} \qquad (1),$$

$$z_t = x_t'\beta + u_t,\ y_t \geq 0,\ t = 1, 2, ..., T,$$

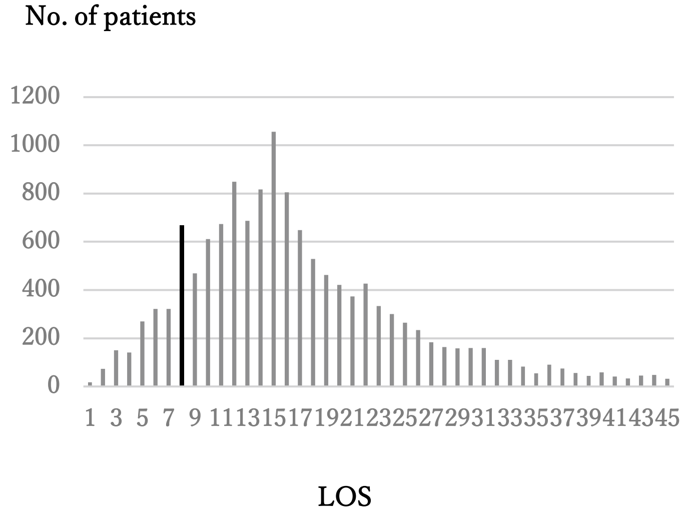
where y_t is LOS, and x_t is a vector of covariates representing characteristics of patients including sex, age, the presence of comorbidities and complications, whether they were admitted as an emergency hospitalization, whether they were admitted as an outpatient from the same hospital or another hospital, the destination following discharge from hospital, and their ICD-10 code (International Classification of Diseases and Related Health Problems, Version 10). Hospital dummy variables were used to estimate the effects of individual hospitals on ALOS. The results show that there were very large differences in ALOS among hospitals, even after eliminating the effects of patient characteristics. LOS for educational hospitalization was mainly determined by the hospitals where patients were staying, and patient characteristics had only a minor influence. The longest and shortest ALOS among the hospitals were 20.3 days and 6.6 days, respectively, which corresponds to a difference of approximately 14 days and a ratio greater than three between the maximum and minimum ALOS. However, the difference in maximum and minimum average medical expenditure per day was 3,676 yen, equivalent to just 13% of the overall average daily medical expenditure per patient, which is a far smaller difference compared with that observed in ALOS. The difference in medical expenditure per hospitalization is considered to be mainly caused by LOS.

II-2. Analysis of patients hospitalized for regular medical treatment

In the previous section, we evaluated LOS and medical expenditure for educational hospitalization. We found a large variation in ALOS among hospitals, and that the ALOS of some hospitals was unreasonably long even after eliminating the effects of various patient characteristics. However, unlike ALOS, the differences in average daily medical expenditure among hospitals were rather small; the difference between the largest and smallest was just 13% of the overall average. The total medical expenditure per hospitalization is mainly determined by LOS. However, educational hospitalization is a special hospitalization program that only admits patients with diabetes. The same findings might not hold for patients with type 2 diabetes who were hospitalized for regular medical treatment (hereafter, regular patients). The treatments for regular patients may vary depending on the patient's condition, and heterogeneity among regular patients may be much larger than that of patients undergoing educational hospitalization. Nawata and Kawabuchi (2016) analyzed LOS and medical expenditure for regular patients using the same dataset described in the previous section. Of the 27,861 patients included in the dataset, 22,430 (approximately 80%) were classified under DPC code 100070xxxxxx0x. Figure 3 shows the distribution of LOS; ALOS was 17.4 days, and the average medical expenditure per hospitalization was 461,431 yen. In the analysis, they used data for patients whose principal disease was diabetes and who attended clinical departments that mainly treat diabetes. A total of 14,193 regular patients satisfied these criteria. The distribution has a much heavier right tail than that for educational hospitalization. After excluding patients who underwent operations or had missing values for covariates, the final dataset used in the analysis included 60 hospitals, each with at least 60 regular patients, and an overall total of 12,666 patients.

The overall ALOS for the 12,666 patients was 18.1 days and the standard deviation (SD) was 12.7 days. The average medical expenditure was 461,680 yen and SD was 273,253 yen.

Figure 3. Distribution of length of stay (LOS) for regular patients

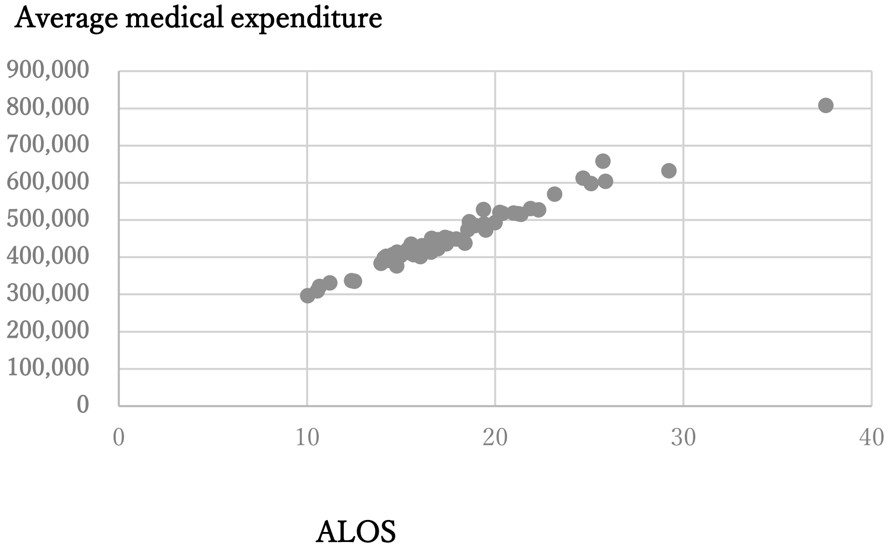


Source: Nawata and Kawabuchi (2016)

The coefficients of variation (defined as SD/average) were 70% for LOS and 59% for medical expenditure. Those for educational hospitalization were 49% and 41%, respectively, suggesting that the variation among regular patients was larger than that among patients undergoing educational hospitalization, which was expected. The maximum and minimum ALOS among the hospitals in the dataset were 37.6 and 10.0 days, respectively, which equates to a difference of 27.6 days, with the maximum ALOS being 3.8 times larger than the minimum. The maximum and minimum SD among hospitals were 28.4 days and 4.7 days, respectively. The maximum was six times larger than the minimum, revealing a very large variation in ALOS among hospitals, and implying heteroscedasticity in the variances among hospitals. Figure 4 shows the relationship between ALOS and average medical expenses (per hospitalization) among the hospitals in the dataset. The correlation coefficient is 0.984 (extremely close to 1), and there is a strong and almost linear relationship between the two variables. This suggests that, despite large heterogeneity among patients, ALOS was the largest determinant of average medical expenditure.

As mentioned previously, the distribution of LOS (Figure 3) has a heavy tail on the right side; therefore, the Box-Cox transformation was used as described in the previous section. Because the SDs were quite different among hospitals, the method proposed by Nawata (2015) was used in the analysis to provide consistent estimators even under heteroscedasticity. The covariates used to represent patient characteristics were largely the same as those listed in the previous section, and the effects of hospitals were estimated using hospital dummy variables. Based on the results of the estimation, the largest difference in LOS caused by patient characteristics can be calculated by considering two male patients staying at the same hospital who represent the worst- and best-case characteristics, respectively. One patient is age 80, has 4 comorbidities and 4 complications, was referred by another hospital,

Figure 4. Average length of stay (LOS) and average medical expenditure per hospitalization for regular patients



Source: Nawata and Kawabuchi (2016)

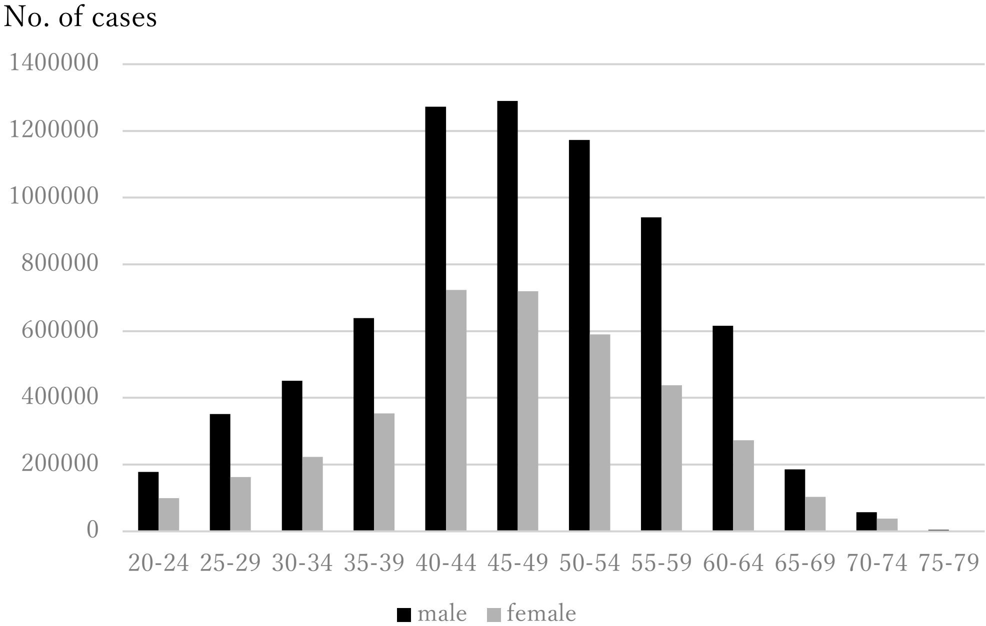
and has the ICD-10 code E11.7. The other patient is age 50, has no comorbidities or complications, was not referred by another hospital, and has the ICD-10 code E11.9. All other covariates were given the same values. The maximum difference in LOS between the two patients was calculated as 1.534. In contrast, the maximum difference between the LOS estimates for the hospital dummy variables was 2.873, which is much larger than that caused by patient characteristics. Moreover, compared with the estimate for the hospital where the ALOS was the shortest, the differences in ALOS estimates for the hospital dummy variables at 21 hospitals (i.e., more than one third of the total of 60 hospitals in the dataset) exceeded the value of 1.534 attributed to patient characteristics, as calculated above. This result suggests that the ALOS for some hospitals was unreasonably long even after eliminating the effects of patient characteristics. It may be necessary for these hospitals to explain why their LOS is so long and to revise their medical practices and hospitalization schedules accordingly. The average age of the patients in the dataset was 64, indicating that many patients were of working age. It is often difficult for working patients to stay in hospital for a period as long as two weeks or more. Long LOS may be a factor preventing people of working age from seeking proper treatment in the early stages of diabetes.

Daily medical expenditure was also analyzed using the regression model. The differences in average daily medical expenditure among hospitals were relatively small. The largest difference among hospitals was only 12% of the overall average, after correcting for patient characteristics. This implies that medical expenses are mainly determined by LOS even when the effects of patients' individual characteristics are eliminated.

III. Analysis of the JMDC Claims Database of health checkup results

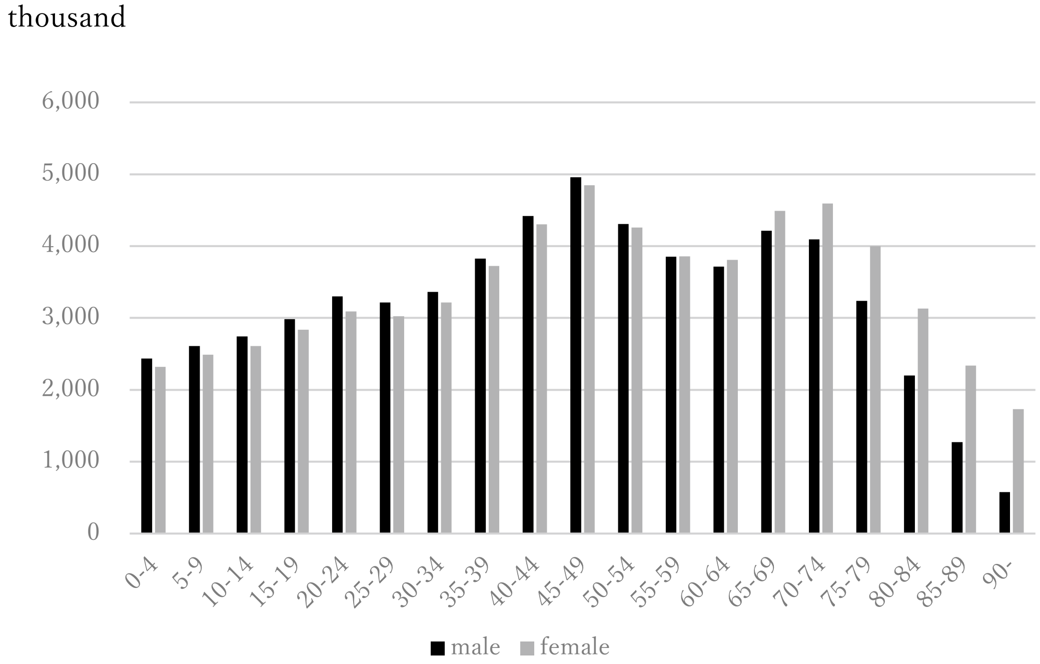
In Japan, most employees aged 40 or over are required to undergo mandatory health checkups once a year, and their family members can also receive medical checkups on a voluntary basis. In this section, we analyzed the BG level results from 13,157,681 health checkups undergone by 3,233,271 individuals for whom data was available in the JMDC Claims Database. The sample period was January 2005 to September 2019. The BG levels analyzed were obtained by the fasting plasma glucose (FPG) test. In the FPG test, the recipient does not eat or drink anything (except water) for at least 10 hours prior to the BG level (mg/dL; hereafter, mg) being measured. In addition to BG level, hemoglobin A1c (HbA1c, %) was also considered in the analysis. A diagnosis of diabetes is mainly determined on the basis of these indicators (Japan Diabetes Society, 2020). Figure 5 shows the age distribution, by sex, of the individuals included in the analysis. Figure 6 displays the age distribution of the overall Japanese population, by sex, in 2019 (Statistics Bureau of Japan, Ministry of Internal Affairs and Communications, 2020). Because health checkups mainly cover individuals in the working population, the fact that there are relatively low numbers of younger and older people and women in the dataset is an issue. In particular, it is known that the prevalence of diabetes is higher among older people, and therefore collecting appropriate data for older people will become an important task in the future.

Figure 5. Age distribution by sex of the individuals in the analysis



Made from JMDC Clams Database (2021)

Figure 6. Age distribution of the overall Japanese population by sex in 2019



Made from Statistic Bureau of Japan (2020)

III-1. Blood glucose level

Figure 7 shows the distribution of BG levels obtained from 10,874,321 test results (cases). The mean BG level was 95.2 mg, the median was 92 mg, SD was 18.4 mg, the minimum was 20 mg, and the maximum was 899 mg. Under the current criteria for diagnosing diabetes on the basis of BG level, a person is diagnosed with diabetes if their BG level is ≥126 mg, prediabetes if their BG level is 110-125 mg, and is considered normal if their BG level is <110 mg (Araki et al., 2020). Under these criteria, 4.21% of all cases showed diabetes, 6.21% showed prediabetes, and 89.58% were normal.

To analyze this data, we first consider the following model (Model A) to adjust for age, sex, whether the test recipient is a family member or not, and year-on-year trends:

$$B\_Glucose_i = \beta_1 + \beta_2 Age1 + \beta_3 Age1^2 + \beta_4 Female + \beta_5 Family + \beta_5 t1 + u_i \quad (2),$$

where $B\_Glucose_i$ is BG level, *Age*1 is actual age minus 17 (because the minimum age in the dataset is 18), *Female* is the dummy variable that takes 1 for female and 0 for male, *Family* is the dummy variable that takes 1 for family member and 0 for employee, and *t*1 is a trend term equal to the year of the test result minus 2004 (because the earliest year for which data was available was 2005). For the variables in Model A, the average age is 46.6, the proportion of women is 34.3%, and the proportion of family members is 17.6%. Figure 8 shows the distribution of cases by year. The estimation results are presented under the

Figure 7. Distribution of blood glucose levels

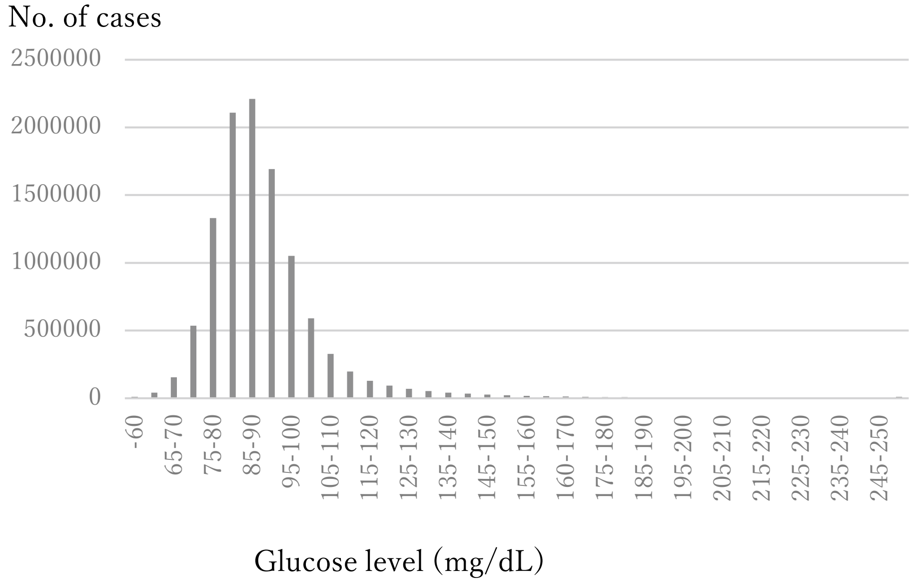
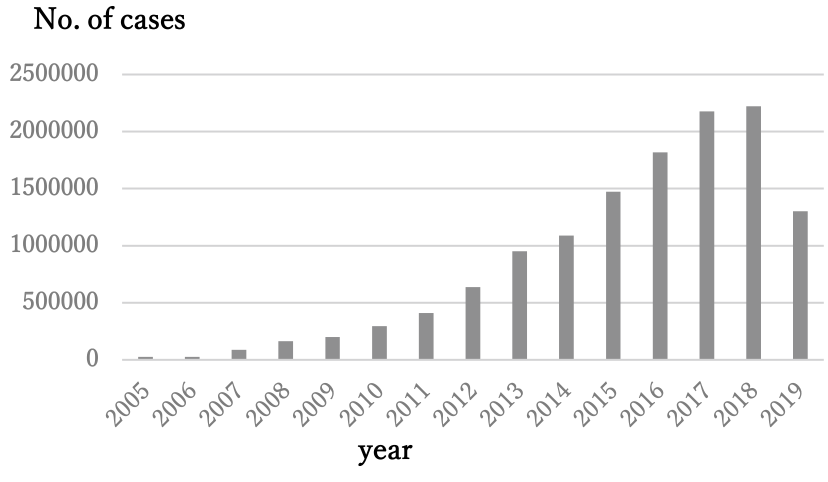


Figure 8. Number of cases by year



heading 'Model A' in Table 3. Because the size of the dataset is very large, all estimates are significant at any reasonable level. For age, it is the squared term that is significant, which implies that the effects of age may not be linear. For example, the BG level increases by 4.4 mg on average between ages 40 and 50, it increases by 4.9 mg on average between ages 50 and 60, and the average increase is as much as 5.4 mg between ages 60 and 70. The average BG level for women is 5.5 mg lower than that for men, and the average BG level for family members is 1.6 mg lower than that for employees. The estimated value for the year-on-year trend term is positive, with an annual increase in BG level over the period covered by the dataset, which was not a trend observed in blood pressure (Nawata, 2021a).

Next, we consider the following model (Model B), which includes various results obtained from the health checkups as covariates:

$$\begin{aligned} \text{B\_Glucose}_i = {} & \beta_1 + \beta_2 Age1 + \beta_3 Age1^2 + \beta_4 Female + \beta_5 Family + \beta_6 t1 + \beta_7 BMI \\ & + \beta_8 SBP + \beta_9 DBP + \beta_{10} HDL + \beta_{11} LDL + \beta_{12} Triglyceride + \beta_{13} ALT \\ & + \beta_{14} AST + \beta_{15} GGT + \beta_{16} Weight\_1 + \beta_{17} Weight\_20 + \beta_{18} Eat\_fast \\ & + \beta_{19} Late\_supper + \beta_{20} No\_breakfast + \beta_{21} Exercise + \beta_{22} Activity \\ & + \beta_{23} Walk\_fast + \beta_{24} Sleep + \beta_{25} Alcohol\_freq + \beta_{26} Alcohol\_amount \\ & + \beta_{27} Smoke + u_i \qquad (3). \end{aligned}$$

For this model, 5,472,205 cases without any missing values in covariates were used in the analysis. The definitions and summaries of the variables are presented in Table 2, and the estimation results are given under the heading ‘Model B’ in Table 3. As before, because the dataset is very large, p-values for all covariates except *Smoke* (p-value=0.3264) are small and significant at any reasonable level. For the variables *Age1* to *t1*, listed in Table 3, we obtain the same signs as those obtained using Model A. Regarding the other covariates, the estimated values for *BMI*, *SBP*, *Triglyceride*, *ALT*, *GGT*, *Eat_fast*, *Late_supper*, *No_breakfast*, *Activity*, and *Alcohol_amount* are positive, while those of *DBP*, *HDL*, *LDL*, *AST*, *Weight_1*, *Weight_20*, *Excercise*, *and Alcohol_freq* are negative. As expected, a larger value of *BMI* corresponds to an increased BG level. For example, reducing BMI by 3.7 points (which is the SD of BMI) also reduces the BG level by 2.6 mg. In terms of blood pressure (BP), the results show that higher systolic BP (*SBP*) increases BG levels; however, higher diastolic BP (*DBP*) reduces BG levels. Although *LDL* is known as ‘bad’ cholesterol, the results show that higher *LDL* actually reduces BG levels, as is also the case for *HDL*, or ‘good’ cholesterol. The covariates for weight change take negative values, although the magnitude of their effects on BG levels is comparatively small. The covariates representing dietary habits take positive values, suggesting that making improvements in one’s diet can reduce BG levels. The covariates relating to exercise and physical condition are all negative, except *Activity*, and this suggests that taking exercise and improving one’s physical condition may reduce BG levels. For alcohol consumption, the variable *Alcohol_freq* is negative, but the variable *Alcohol_amount* is positive. Given that the absolute value for the *Alcohol_amount* variable is almost twice as large as that for *Alcohol_freq*, and that *Alcohol_amount* takes 5 different integer values in the model, drinking alcohol (and particularly heavy drinking) can be considered to increase BG levels.

In the analysis using Model B, we assumed that the covariates from *SBP* to *GGT* affect the BG level. However, there is also the potential for the opposite relationship, whereby the BG level affects the covariates (i.e., the variables are endogenous). If the covariates were the causes and the BG level were the result, Model B would only indicate that there exists a relationship between the BG level and the covariates. In this case, it would not be possible to obtain useful information that could be applied toward diabetes treatments. For example, in terms of the relationship between BG level and BP, there would be no basis to argue that it is high BG levels that cause high BP, or high BP that causes high BG levels. Moreover, by

Table 2. Definitions and summaries of covariates used in models

Variable	Definition	Summary Average	SD
Age		47.7	10.03
Female	1: female; 0: male	1: 30.7%; 0: 69.3%	
Family	1: family member; 0: employee	1: 22.2%; 0: 77.8%	
BMI	body mass index = weight (kg)/height(m)^2	23.0	3.67
SBP	systolic blood pressure, mmHg	119.9	16.3
DBP	diastolic blood pressure, mmHg	74.3	11.8
HDL	high-density lipoprotein cholesterol, mg/dL	63.3	16.8
LDL	low-density lipoprotein cholesterol, mg/dL	121.6	31.0
Triglyceride	mg/dL	108.4	86.3
ALT	alanine aminotransferase, U/L	23.3	17.8
AST	aspartate aminotransferase, U/L	22.4	10.7
GGT	γ-GT (glutamyl transferase), U/L	38.2	45.5
Weight_1	1: weight changed by 3 kg or more in a year; 0: otherwise	1: 26.7%; 0: 73.3%	
Weight_20	1: weight increased by 10 kg or more since age 20; 0: otherwise	1: 35.3%; 0: 64.7%	
Eat_Fast	1: eating faster than other people; 0: otherwise	1: 32.2%; 0: 67.8%	
Late_Supper	1: eating supper within 2 h before bedtime three times or more per week; 0: otherwise,	1: 32.5%; 0: 67.5%	
No_breakfast	1: not eating breakfast three times or more per week; 0: otherwise	1: 18.5%; 0: 81.5%	
Exercise	1: doing exercise for 30 minutes or more twice or more per week for more than a year; 0 otherwise	1: 21.8%; 0: 78.2%	
Activity	1: doing physical activities (walking or equivalent) for one hour or more daily, 0: otherwise	1: 35.6%; 0: 64.4%	
Speed	1: walking faster than other people of a similar age and the same sex; 0: otherwise	1: 45.3%; 0: 54.7%	
Sleep	1: sleeping well; 0: otherwise	1: 59.5%; 0: 40.5%	
Alcohol_freq	0: not drinking alcoholic drinks; 1: sometimes; 2: every day	0: 40.8%; 1: 33.9%; 2: 25.4%	
Alcohol_amount	0: not drinking; 1: drinking less than 180 ml of Japanese sake wine (with an alcohol percentage of about 15%) or equivalent alcohol in a day when drinking; 2: drinking 180–360 ml; 3: drinking 360–540 ml; 4: drinking 540 ml or more	0: 40.8%; 1: 22.3%; 2: 22.7%; 3: 10.6%; 4: 3.7%	
Smoke	1: smoking; 0: otherwise	1: 25.8%; 0: 74.2%	

SD: standard deviation

including BP in the model, it would not be possible to observe or evaluate the effects of lifestyles, or to test and establish the existence of causal relationships, such as 'lifestyle→BP→BG levels'. Therefore, we next consider the following model (Model C), which excludes covariates that could be endogenous (known in econometrics as a 'reduced-form model'):

$$B\_Glucose_i = \beta_1 + \beta_2 Age1 + \beta_3 Age1^2 + \beta_4 Female + \beta_5 Family + \beta_6 t1 + \beta_7 BMI$$
$$+ \beta_{16} Weight\_1 + \beta_{17} Weight\_20 + \beta_{18} Eat\_fast + \beta_{19} Late\_supper$$

Table 3. Analytical results for Models A, B and C

	Model A		Model B		Model C	
Variable	estimate	SE	estimate	SE	estimate	SE
Constant	85.3092	0.0381	58.6161	0.1049	62.4206	0.0843
Age0	0.3237	0.0021	0.1509	0.0034	0.1459	0.0034
$Age0^2$	0.0021	0.0000	0.0040	0.0001	0.0047	0.0001
Female	−5.5399	0.0146	−1.5173	0.0230	−3.2875	0.0220
Family	−1.6364	0.0183	−0.8494	0.0246	−0.6039	0.0249
t1	0.0543	0.0020	0.0402	0.0036	− 0.0064	0.0036
BMI			0.7036	0.0028	1.0620	0.0026
SBP			0.1237	0.0008		
DBP			−0.0469	0.0011		
HDL			−0.0140	0.0006		
LDL			−0.0125	0.0003		
Triglyceride			0.0177	0.0001		
ALT			0.1041	0.0008		
AST			−0.0974	0.0012		
GGT			0.0244	0.0002		
Weight_1			−0.2023	0.0173	−0.3576	0.0176
Weight_20			−0.1334	0.0191	0.5672	0.0191
Eat_Fast			0.0770	0.0162	0.0165	0.0164
Late_Supper			0.6693	0.0168	0.6985	0.0170
No_breakfast			0.5448	0.0200	0.6768	0.0203
Exercise			−0.0947	0.0190	−0.4245	0.0192
Activity			0.1529	0.0162	0.0207	0.0164
Speed			−0.5074	0.0152	0.5672	0.0191
Sleep			−0.1293	0.0152	−0.0480	0.0154
Alcohol_freq			−0.0840	0.0145	−0.0037	0.0145
Alcohol_amount			0.1716	0.0099	0.4297	0.0099
Smoke			−0.0178	0.0181	0.4232	0.0182
R^2	0.0943		0.160911		0.1364	
No. of Cases	10,874,321		5,472,205		5,496,799	

SE: standard error

$$+ \beta_{20} No\_breakfast + \beta_{21} Exercise + \beta_{22} Activity + \beta_{23} Walk\_fast + \beta_{24} Sleep + \beta_{25} Alcohol\_freq + \beta_{26} Alcohol\_amount + \beta_{27} Smoke + u_i \quad (4).$$

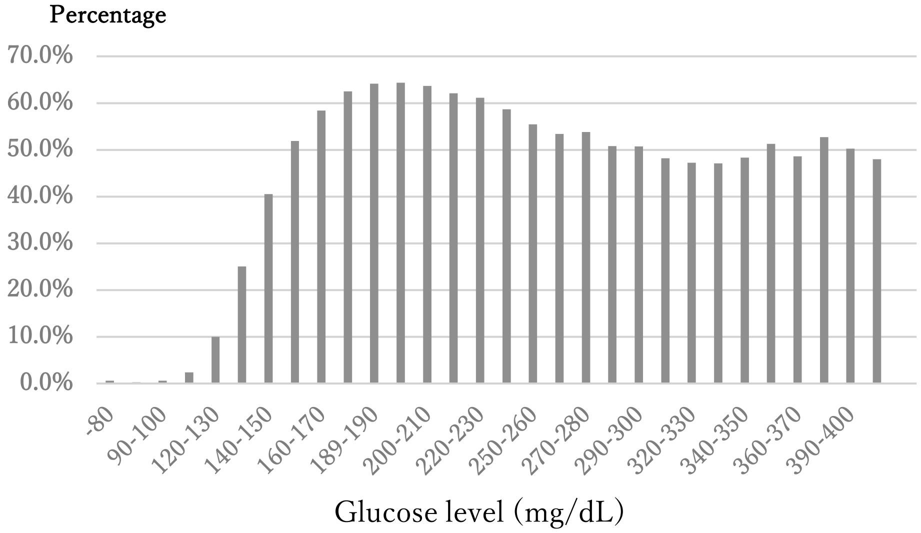
The estimation results are presented under the heading ‘Model C’ in Table 3. Although the size of the dataset is very large, the estimates of *t1* (p-value=0.072), *Eat_fast* (p-value=0.313), and *Activity* (p-value=0.218) are not significant, even at the 5% level. Regarding lifestyle factors, the estimated value of the *BMI* variable is large (1.062), and a reduction of BMI by 3.7 points reduces the BG level by approximately 4 mg. This means that the prevention of obesity is important in controlling BG levels. For weight change, the estimated value of *Weight_1* is negative, while that of *Weight_20* is positive. All estimated values of covariates relating to dietary habits are positive, which suggests that making improvements to eating habits can reduce BG levels. For the variables representing exercise and physical condition, the estimated values of *Exercise*, *Walk_fast*, and *Sleep* are negative, positive, and negative, respectively, from which it is difficult to draw any clear conclusions. Increased alcohol consumption corresponds to increased BG levels, and furthermore, in this model, smoking also appears to result in higher BG levels.

III-2. Insulin injection and medicines controlling blood glucose level

When patients cannot control their BG levels through making lifestyle improvements, they are usually given insulin injection and/or BG-controlling medicines (hereafter, BG medicines) as treatment. Among the 11,523,541 responses to questions regarding the use of BG medicines in our dataset, 3.33% stated that they were using BG medicines. Obviously, an individual’s use of BG medicines depends on his/her BG level. A person with a high BG level is more likely to use BG medicines, which gives rise to the endogeneity problem. We cannot simply introduce a BG medicine dummy (1: taking BG medicines, 0: not taking BG medicines) in the regression model and examine its effect. In fact, if a BG medicine dummy is added into ‘Model B,’ its estimated value is 41.7 mg, which spuriously implies that the use of BG medicines increases BG levels. In their analysis of hypertension, Nawata (2021a) and Nawata et al. (2018) evaluated the effect of antihypertensive medicines by using the expected value of a medicine dummy to solve the endogeneity problem. However, if this method is also applied to BG levels, the estimated expected value for the BG medicine dummy becomes 56.6 mg, and the effect of the BG medicines cannot be correctly evaluated. This suggests that BG behaves differently to BP.

Figure 9 shows the relationship between BG levels and the percentage of people taking BG medicines at those BG levels. It is clear that the percentage of people taking BG medicines increases as the BG level increases up to approximately 180 mg, but then flattens out. The usage percentage is 2.37% for a BG level of 100-120 mg and increases to 64.34% for a BG level of 190-200 mg. However, the percentage then decreases if the BG level exceeds 200 mg, and becomes 48.18% (i.e., less than half) at a BG level of 300-310 mg. As above, the relationship between BG level and the percentage of people taking BG medicines is

Figure 9. Relationship between blood glucose (BG) levels and the percentages of people taking BG medicines (including insulin) at those BG levels



rather complicated. There is a possibility that the data contain not only fasting BG levels but also values measured just after eating meals. For example, a BG level of 200 mg is the threshold for diabetes in the random plasma glucose test, which is a blood test that can be taken at any time of the day. In this analysis, unlike Nawata (2021b), we therefore divide the data into two groups, using a BG level of 200 mg as the boundary. If fasting and non-fasting BG values were randomly mixed within the dataset, other health variables would not be expected to be significantly different between the two groups. Table 4 shows the values of other health variables for the two BG level groups (<200 mg and ≥200 mg). For most of the variables, there are large differences between the two groups, and the majority of average values for health variables in the ≥200 mg group can be considered as unhealthy. This indicates that the presence of BG levels over 200 mg in the dataset is not caused by a mixture of measurement methods.

This means that nearly half of those people with BG levels over 200 mg (which implies serious diabetes) were not taking BG medicines. The proportion of people with BG levels over 200 mg was 0.38%, which seems a small number. However, the proportion of people with BG levels over 126 mg (and diagnosed with diabetes) is 4.21% of all cases, and 9.1% of all diabetic cases are in the ≥200 mg group. This suggests that many people with serious diabetes might not be receiving the necessary treatment. Moreover, for cardiovascular disease (such as heart disease), cerebrovascular disease (such as stroke), and chronic renal failure, which are very serious and costly diseases, the proportion of people with these disease histories is related to BG levels. When the BG level is under 200 mg, the proportions are 1.86% for cardiovascular disease, 0.86% for cerebrovascular disease, and 0.28% for chronic renal failure, among a total 8,831,934 cases. However, when the BG level is over 200 mg, the proportions are 4.66% for cardiovascular disease, 1.78% for cerebrovascular disease,

Table 4. Values of variables by BG group

	BG below 200mg		BG 200mg or over	
Variable	Mean	SD	Mean	SD
Age	47.7	10.03	51.7	8.5
Female	0.40		0.16	
Family	0.23		0.08	
BMI	23.0	3.65	26.5	4.8
SBP	63.4	16.27	132.6	18.8
DBP	121.5	11.81	81.5	12.1
HDL	107.8	16.77	52.9	15.4
LDL	119.8	30.96	131.0	37.9
Triglyceride	74.3	84.99	213.3	200.0
ALT	23.2	17.73	36.6	29.5
AST	22.3	10.61	28.1	20.8
GGT	38.0	45.13	72.2	89.3
Weight_1	0.266		0.343	
Weight_20	0.352		0.558	
Eat_Fast	0.321		0.381	
Late_Supper	0.324		0.399	
No_breakfast	0.185		0.228	
Exercise	0.218		0.199	
Activity	0.357		0.297	
Speed	0.453		0.354	
Sleep	0.597		0.549	
Alcohol_freq	0.847		0.818	
Alcohol_amount	1.142		1.199	
Smoke	0.258		0.417	
U_sugar	1.044	0.36	3.975	1.347
U_protein	1.148	0.47	1.673	1.088
No. of cases	5,390,377		27,388	

U_sugar: urine sugar, integers of 1-5; 1: undetected, 2: around 50 mg/dL, 3: around 100 mg/dL, 4: around 250 mg/dL, and 5: around 500 mg/dL or over; 1 is normal and 5 is worst case
U_protein: urine protein, integers of 1-5; 1: undetected, 2: around 15 mg/dL, 3: around 30 mg/dL, 4: around 100 mg/dL, and 5: around 250 mg/dL or over

and 0.63% for chronic renal failure, among a total of 43,086 cases. The proportions of people with these diseases for BG levels over 200 mg are 2.51, 2.08, and 2.25 times as large, respectively, as those for BG levels under 200 mg. This clearly demonstrates that the percentage of people with these disease histories increases with higher BG levels.

Next, we divide cases with a BG level over 200 mg into two further groups. One group consists of people taking BG medicines (medicine group), and the other consists of people not taking BG medicines (no medicine group). Table 5 presents the average values of the variables for the two groups. In the no medicine group, people are younger and the proportion of women is higher than in the medicine group. The variables generally show unhealthier values in the no medicine group than in the medicine group. In particular, the differences in the average values for *LDL*, *Triglyceride*, and *GGT* between the groups are large (12%, 16%, and 15% higher, respectively, in the no medicine group than in the medicine group). For variables relating to lifestyle factors, there are large differences in *Eat_Fast* and *Exercise*; the former shows the expected effect, but the latter shows the opposite, and therefore a further analysis that considers age, sex, and other variables may be necessary for these values. For BG level and HbA1c, the values for the medicine group are lower than those of no medicine group, despite the fact that the average age is higher in the medicine group, which can be considered to demonstrate the positive effects of BG medicines.

III-3. Hemoglobin A1c

In addition to BG levels, HbA1c is also used as an indicator for diabetes. HbA1c is the stable glycosylation of hemoglobin A0 and reflects the average of 1-2 months of BG levels before the test is performed (Japan Diabetes Society, 2020). If HbA1c is 6.5% or higher, a person is diagnosed with diabetes (however, under Japanese clinical practice guidelines (Japan Diabetes Society, 2019), it is recommended that at least one BG test is also carried out to confirm the presence of diabetes, rather than relying solely on the HbA1c test). Our dataset contained 10,519,161 test results for HbA1C, and their distribution is shown in Figure 10. The average HbA1c value is 5.54%, the median is 5.4%, SD is 0.612%, the minimum is 3.0%, and the maximum is 19.9%. Based on the HbA1c threshold of 6.5% or over, 4.18% of test results in our dataset suggest the presence of diabetes. When combined with the BG level criteria for diabetes, 2.96% of cases indicate diabetes for both measures, and 5.11% of cases indicate diabetes for at least one measure.

Figure 11 shows the distribution of BG levels and HbA1c. The correlation coefficient is 0.7371, and a clear correlation can be seen between the two factors, such that when one increases, the other also increases. Figure 12 shows the relationship between HbA1c levels and the percentage of people taking BG medicines at those HbA1c levels. The percentage taking BG medicines increases as HbA1c increases up to an HbA1c value of 8.4%; however, it declines thereafter, which is a similar pattern to that observed for BG levels (Figure 9). (Although we also conducted the same analyses for HbA1c as we did for BG, the findings for HbA1c are very similar to those obtained for BG, and therefore the detailed results are

Table 5. Values of variables for individuals with BG levels of 200 mg or over, by BG medicine group

	Not taking BG medicines		Taking BG medicines	
Variable	Mean	SD	Mean	SD
Age	50.4	8.4	52.8	8.2
Female	0.18		0.15	
Family	0.09		0.08	
t1	11.0	2.1	11.0	2.1
BMI	26.5	4.70	26.6	4.80
SBP	133.8	19.6	131.9	18.0
DBP	83.1	12.4	80.4	11.6
HDL	51.9	14.5	53.9	16.2
LDL	139.2	39.9	123.4	34.5
Triglyceride	233.3	216.2	198.1	184.0
ALT	38.6	32.5	35.2	26.6
AST	28.6	22.3	27.7	19.5
GGT	78.2	91.1	67.1	87.9
Weight_1	0.44		0.39	
Weight_20	0.85		0.79	
Eat_Fast	0.25		0.17	
Late_Supper	0.38		0.39	
No_breakfast	0.42		0.38	
Exercise	0.28		0.18	
Activity	0.18		0.21	
Speed	0.30		0.29	
Sleep	0.37		0.34	
Alcohol_freq	0.34	0.47	0.34	0.48
Alcohol_amount	0.58	0.49	0.55	0.50
Smoke	0.54		0.54	
U_Sugar	4.04	1.3	3.90	1.38
U_Protein	1.60	1.0	1.71	1.14
B_Glucose	253.4	51.5	244.6	45.7
HbA1c	10.1	2.1	9.29	1.7
No. of cases	10,315		12,774	

SD: standard error

Figure 10. Distribution of HbA1c levels

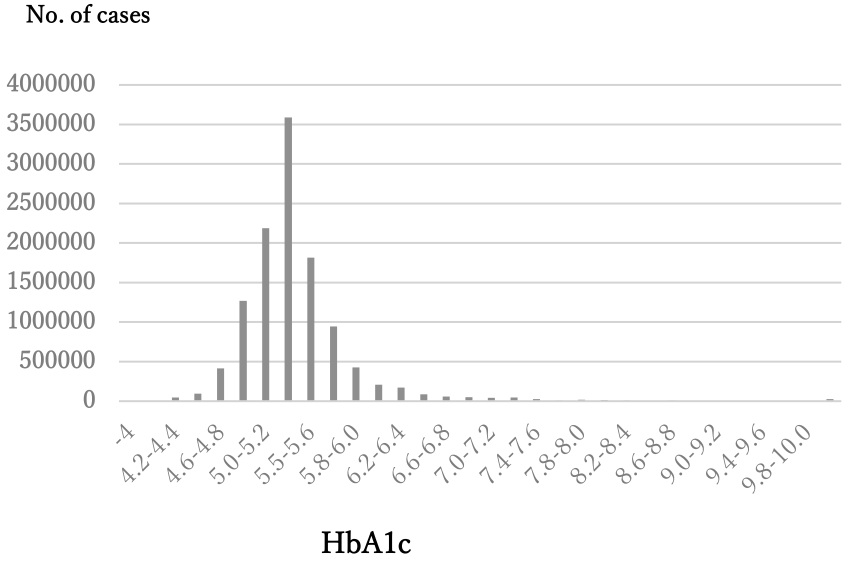


Figure 11. Distribution of blood glucose levels and HbA1c

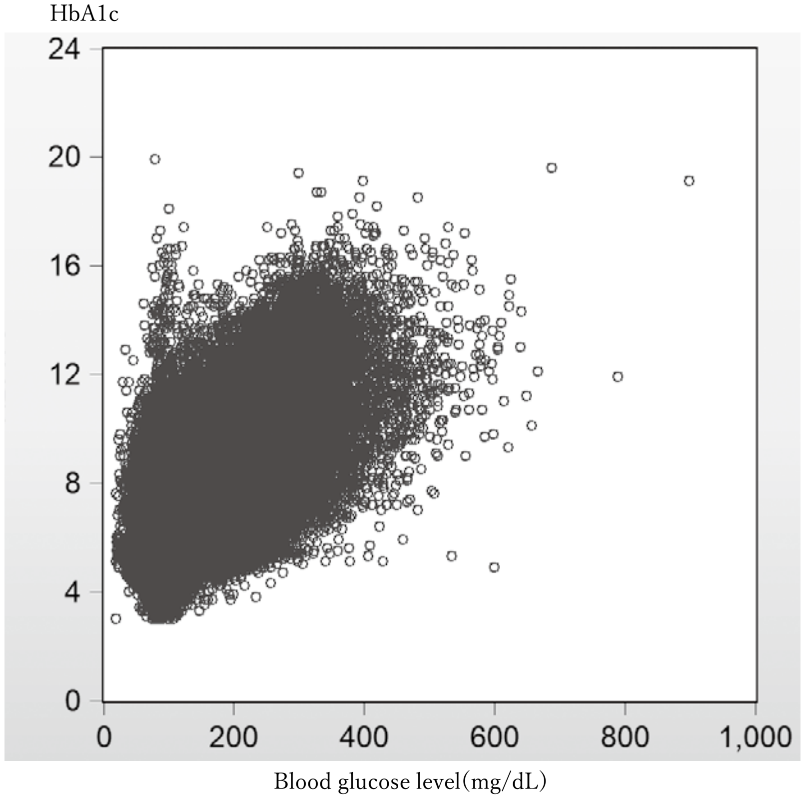
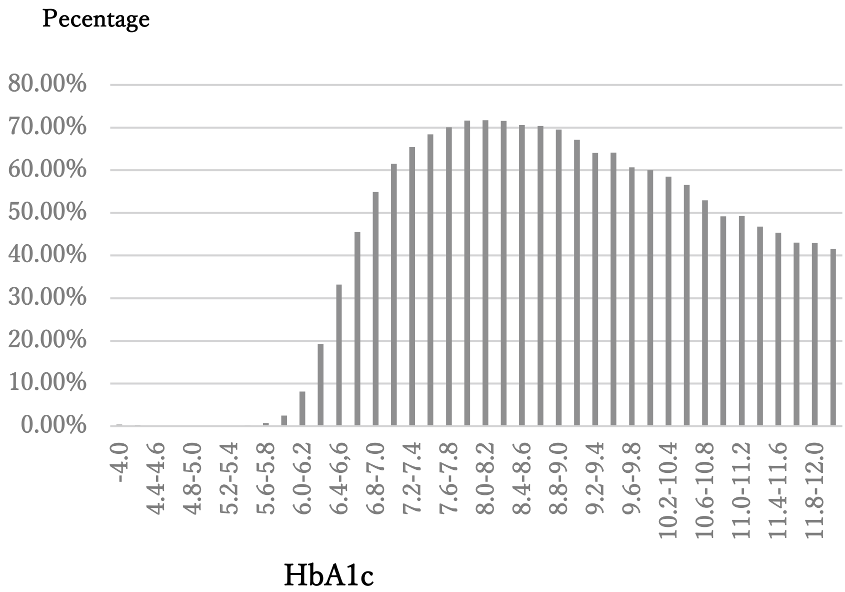


Figure 12. Relationship between HbA1c levels and the percentages of people taking blood glucose medicines (including insulin) at those HbA1c levels



not presented here to avoid unnecessary duplication.)

IV. Discussion

IV-1. Educational hospitalization: A potential problem of over-provision of health care

From the analyses conducted in this study, it is clear that there are very large differences in LOS for educational hospitalization. The minimum ALOS was 5.7 days and the maximum was 27.1 days among the hospitals in our dataset. Even after eliminating effects relating to individual patient characteristics, there still exist large differences in ALOS among hospitals, and total medical expenditure (per hospitalization) is mainly determined by LOS. The important question is whether a long LOS brings sufficient benefits to patients to justify it. Nagashima et al. (2005) compared four-day (three-night) and two-week stays for educational hospitalization. They reported that that there were no differences in their effects. Yamamoto, Takeuchi, and Ichikawa (2000) evaluated the effects of the introduction of a clinical path and the standardization of educational programs. They reported that when ALOS was shortened from 25.2 days to 14.6 days, there was better cooperation among medical staff, and comprehensive test scores were improved. Kobori et al. (2006) analyzed the effects of changing from a paper-based to a computerized clinical path. They reported similar outcomes when the ALOS was shortened from 14 days to 10 days. Tsurumi (2002) also reported that, through the introduction of a clinical path and the standardization of treatments, it became possible to give guidance based on the patients' individual schedules and for the medical team to operate more effectively, leading to improved understanding of diet therapy for diabetes and improved fasting BG levels. We were unable to find any studies that showed there were sufficient benefits in long LOS (two weeks or more) to outweigh the costs of hospitalization.

In their analysis of 502 DPC hospitals, Ii and Watanabe (2021) showed that educational hospitalization for patients with diabetes, which ordinarily ranks as one of the most common reasons for scheduled (elective) hospitalization, decreased sharply throughout the COVID-19 pandemic, falling by 31.1% in the first wave of the pandemic (April-May 2020), 28.9% in June 2020, 13.6% in the second wave (July-August 2020), 11.8% in the third wave (November 2020-January 2021), 25.8% in February-March 2021, 15.9% in the fourth wave (April-May 2021), and 28% in June 2021, compared with the same pre-pandemic periods in 2019.

Results of investigative studies suggest that organized diabetes self-management education and support (DSMES) is effective in diabetes treatment (He et al., 2017; Ismail et al., 2004; Pillay et al., 2015a; Pillay et al., 2015b). Japanese clinical practice guidelines (Japan Diabetes Society, 2019, pp. 107-109) therefore strongly recommend the use of DSMES among diabetes patients. However, we were unable to find any existing studies that examine the benefits of educational hospitalization compared with other DSMES methods.

Previous studies have found that continuous care provided by community-based multidisciplinary primary health care experts as part of DSMES is extremely effective (Norris et al., 2020; Powers et al., 2015) and that DSMES can reduce unnecessary hospital admissions (Powers et al., 2015). There is also a growing body of evidence pointing to the benefits of using smartphone applications and other technologies in DSMES (Dickinson et al., 2019; Nelson, 2020). The time has come to reconsider whether educational hospitalization for diabetes is truly necessary, rather than continuing to use it without questioning its objectives and cost-effectiveness. At the very least, limits should be imposed on excessively long educational hospitalizations. We hope that future policies will encourage a shift from inpatient to outpatient care and promote more community-based initiatives.

In terms of discharge outcomes for diabetes patients hospitalized for regular medical treatment, only 131 out of the 14,193 regular patients in our dataset were completely cured, and more than 99% of patients required some type of follow-up care after leaving hospital. It has also been reported that many patients with diabetes do not follow their prescribed treatment methods (Wilke et al., 2013); that medical expenses for patients with diabetes increase as body mass index (BMI) increases (Dilla et al., 2012); and that people diagnosed with diabetes are more likely to make efforts to improve their lifestyle than people without diabetes, but that the effects only continue for a short period (Slade, 2012). This evidence may also suggest the importance of considering continuous treatment and prevention for patients with diabetes.

IV-2. High blood glucose levels: A potential problem of under-provision of health care

Nawata and Kimura (2017) estimated that people with kidney failure would face medical bills 14.5 times higher on average than those without kidney failure. Therefore, we cannot ignore the potential effects on medical expenses for people with GB levels of 200 mg or over, despite the fact that they represent only 0.38% of all cases in our dataset.

Among patients with exceptionally high BG levels (of 200 mg or over), the proportion of people with serious diseases is much higher than among those with lower BG levels. Moreover, as described previously, the percentage of these people taking BG medicines rises as the BG level increases up to approximately 180 mg, flattens out at a BG level of approximately 180-200 mg, but then declines for BG levels above 200 mg. According to our analysis, less than half of people with a BG level of 300 mg were taking BG medicines. The fact that the percentage of people taking BG medicines decreases with BG levels exceeding 200 mg is, we believe, a new and important finding to come from this analysis. This would suggest that approximately half of people with serious diabetes (with very high BG levels) are not receiving appropriate medical treatment. Clearly, this is a major problem. It is important to give proper guidance regarding lifestyle improvements and treatment during the early stages of diabetes. Not only can this prevent the onset of serious diseases and reduce medical expenses, but it can also improve individual productivity and quality of life, which are very important social issues.

'Specific health checkups' (*tokutei kenshin*) aim to detect designated lifestyle-related diseases such as diabetes in the early stages so that they can be tackled as soon as possible. These screening tests are used to identify people who are at high risk of developing lifestyle-related diseases, who are then given specific health guidance in the hope that targeted lifestyle improvements will help prevent the onset of disease or their condition from worsening. The Ministry of Health, Labour and Welfare (2020d) established a working group in March 2013 to specifically investigate whether screening programs and health guidance initiatives are effective in improving test results and achieving behavioral changes, as well as whether they provide value for money and other benefits.

Iizuka et al. (2021) used data on BG levels from health checkups to analyze whether picking up health signals early leads to disease prevention and improved health, and whether the effect was worth the cost involved. They reached the following four conclusions: (1) people whose health checkup results indicate that their BG level exceeds the set borderline (threshold) value for diabetes increase their use of diabetes-related medical services; (2) however, despite increasing their use of diabetes-related medical services, health checkup recipients show no decrease in BG level in the following year; (3) conversely, people at high risk of diabetes (e.g., those with high blood pressure or high lipids) whose BG test results exceed the set threshold for diabetes, and thus receive targeted medical services, do show a BG decrease in the following year; and (4) for these high-risk individuals, the benefits relating to a reduction in their risk of death as a result of a fall in BG levels are considered to be roughly equal to the increases in medical costs incurred as a result of the threshold value being exceeded. Furthermore, they make the following policy recommendations: (1) appropriate threshold values should be set from the viewpoint of both cost and effectiveness, with preventive services and resources being focused on people at high risk; and (2) there should be appropriate measures to encourage these high-risk individuals to seek preventive medical services.

Similar policy recommendations have been made many times before. Municipalities, health insurance associations, the Ministry of Health, Labour and Welfare, and others have all signaled how important it is to prevent diabetes cases from progressing in severity. It is necessary to examine the reasons why efforts to encourage people at high risk of diabetes to receive preventive medicine have been ineffective and to investigate the factors that hinder organic cooperation between health screening programs and medical care provision.

Table 6 shows the percentage of people with diabetes (BG level of 126 mg or over) and hypertension (BP of 140/90 mmHg or over) who were taking BG and/or antihypertensive medicines, as determined through our analysis of the JMDC Claims Database, divided into two groups by BG level (<200 mg and ≥200 mg).

Table 6. Percentage of people taking BG and antihypertensive medicines, by BG level

BG level	Antihypertensive medicine	BG medicine	Both	None of these	Cases
126–200 mg	47.2%	42.1%	16.0%	26.7%	121,079
200 mg or over	40.1%	52.7%	25.1%	32.3%	17,770

Among such high-risk individuals, the proportion of those taking BG medicine (either taking BG medicine only, or taking both BG medicine and antihypertensive medicine) increases when the BG level exceeds 200 mg. However, the proportion of those not taking either type of medicine is also large. This means that there are many people who have both hypertension and (severe) diabetes but are not receiving treatment from a medical institution.

IV-3. Reviewing the scope of health checkups to reduce over-provision of health care

The details of the main guidelines regarding diabetes screening overseas are shown in Table 7 (ADA, 2021; USPSTF, 2021; CTFPHC, 2012; CDC, 2021). In contrast with the major diabetes screening programs overseas, it is clear that the Japanese specific health checkup program (1) does not evaluate the risk of developing diabetes, although it does include an age limit; (2) carries out annual screening regardless of the risk and/or BG level of the individual; and (3) has not been updated to reflect the best available evidence from the latest clinical research. Compared with other countries, the conditions to qualify for screening in Japan are lax, which increases the number of recipients and thus increases the costs; howev-

Table 7. Major guidelines for diabetes screening

Society / Organization	Target population	Investigations	Interval
American Diabetes Association (ADA, 2021)	・History of gestational diabetes ・Patients with HIV infection before starting, or at the time of changing antiretroviral therapy ・Adults of any age with BMI ≥ 25kg/m²	HbA1c, fasting venous plasma glucose, or 2-hour 75 g oral glucose tolerance test (OGTT)	At least every 3 years if normal results
US Preventive Services Task Force (USPSTF, 2021)	・Adults (age 35-70) with overweight (BMI ≥ 25kg/m²; ≥ 23kg/m² in Asian American persons) or obesity (BMI ≥ 30kg/m²)	・Prediabetes: Fasting plasma glucose 100-125 mg/dL, HbA1c 5.7-6.4%, or 2-hour OGTT 140-199 mg/dL ・Type 2 diabetes: Fasting plasma glucose ≥ 126 mg/dL, HbA1c ≥ 6.5%, or 2-hour OGTT ≥ 200 mg/dL	Screening every 3 years for adults with normal blood glucose levels
Canadian Task Force on Preventive Health Care (CTFPHC, 2012)	Recommendations assume use of validated risk calculator (FINDRISC* preferred) to determine risk for developing diabetes	HbA1c	Adults at : ・Low-to-moderate risk: not recommended ・High risk: every 3-5 years ・Very high risk: annually
Centers for Disease Control and Prevention (CDC, 2021)	Adults (age ≥ 45) with ・Overweight ・Diabetes in a first degree relative ・High-risk ethnic groups ・History of gestational diabetes ・Physically active less than 3 times a week	Fasting plasma glucose, OGTT, or HbA1c	
National Institute for Health and Care Excellence (NICE, 2017)	Encourage the following to have a risk assessment by using a validated self-assessment questionnaire or web-based tools: ・Adults aged ≥ 40 ・Adults aged 25-39 of high-risk ethnic groups ・Adults with conditions that can increase the risk of type 2 diabetes, such as obesity, hypertension, or cardiovascular disease	Fasting plasma glucose, or HbA1c	Adults at : ・High risk: at least annually ・Low risk: at least every 5 years
Japanese Specific Health Checkups (Ministry of Health, Labour and Welfare, 2021)	・Age 40−74	Fasting plasma glucose, or HbA1c	Annually

Source: Created by the authors based on ADA (2021); USPSTF (2021); CTFPHC (2012); CDC (2021); NICE (2017); and Ministry of Health, Labour and Welfare (2021)
*FINDRISC (Finnish Diabetes Risk Score), Available at: https://www.mdcalc.com/findrisc-finnish-diabetes-risk-score (Accessed: September 27, 2022)

er, it is not clear that there is any benefit in providing screening with such broad coverage.

Known risk factors for developing diabetes include family history of diabetes, ethnicity, weight (including at birth and during childhood), fat distribution, exercise, smoking, sleep, diet, environmental factors, medications, and the presence of other diseases. Ideally, primary care physicians should conduct risk assessments for residents under their management and encourage screening tests only for those who would benefit from them.

The fasting blood sugar (FBS) test or the HbA1c test are commonly performed overseas as a means of screening for diabetes. Compared with HbA1c, FBS has the advantage of relatively low cost (in terms of the Japanese medical fee points system, for the test alone FBS is 11 points, while HbA1c is 49 points), but has the disadvantage of greater diurnal fluctuation and between-individual variation. FBS is also affected by the length of fasting, exercise, and stress. HbA1c, on the other hand, has the advantage of not requiring those being tested to prepare for it in advance, such as by fasting, and is highly correlated with diabetic complications such as retinopathy. However, it has the disadvantage that test values cannot be evaluated correctly if there is anemia or blood disease present. The glucose tolerance test is highly reliable as a quality control indicator for FBS and HbA1c tests, but it is not suitable in an ordinary health checkup setting because it requires a further blood sample 2 hours after administration of the glucose solution. The Canadian Task Force on Preventive Health Care (CTFPHC) recommends only HbA1c as a screening test for diabetes on the basis that it is more convenient to the patient if they can be tested at any time without the need for fasting. In health checkups in Japan, either FBS or HbA1c is supposed to be measured; however, in reality, it is often the case that both tests are conducted, resulting in excessive testing.

In Japan, the ‘health checkup’ is an annual event, but in other countries, it is understood that health examinations and screening should be performed periodically, rather than annually, in line with the degree of necessity for each individual test. The interval between diabetes screenings is also based on risk assessment, with high-risk patients being tested annually and lower-risk patients being tested every 3-5 years. It is also worth noting that only those people who received a negative result in screening (i.e., were within the normal range for BG levels, corresponding to 89.6% of people in our dataset) were then included in the next round of screening; the reasoning behind this is that people who screen positive will be given access to suitable medical services and hence do not require rescreening. In Japan, because there is no organic link between health screening and broader medical care provision, even if there are abnormalities found in an annual health checkup, it is often the case that people do not actually seek further medical services, and instead continue to undergo health checkups for no clear reason. In addition, this issue leads to an increase in the number of people not taking curative medicines, regardless of whether or not they have high BG levels.

V. Conclusions and policy recommendations

Japan’s public health system is highly decentralized—as can also be said of Japan’s health policy more generally—and health checkups are conducted widely in municipalities, schools, and workplaces. The labor market in Japan has become increasingly polarized, and the proportion of workers at small- and medium-sized enterprises undergoing health checkups is lower than that at larger companies. Principally, only a limited number of people in Japanese workplaces, such as full-time workers, qualify for health checkups, and there are therefore few methods of accurately identifying high-risk groups among part-time workers, retired people, and the unemployed.

In contrast, employers of designated workers whose occupations are deemed to include working in hazardous conditions are required to provide more frequent (6-monthly, as a minimum) health checkups. Companies with more than 50 employees must also have at least one occupational health physician; however, there are no set quality standards for occupational health physicians, and it is unclear whether their interventions are truly effective.

The scope of the items included in annual health checkups and the range of people who qualify for these checkups have been expanding. In particular, there are many legally-mandated checkups for people aged 40-74 that aim to prevent the onset of lifestyle-related diseases, and checkups that are not legally required but are conducted by insurers and medical providers, including municipalities, health insurance associations, and mutual aid associations. The quality of these checkups and screening programs varies, and their respective risks and benefits are not known. A report by the Organisation for Economic Co-operation and Development (OECD, 2019, p. 27) noted that Japan's multitude of health checkups is "unique in the OECD, and certainly such an extensive range of screenings and tests in place, covering such a large proportion of the population, [is] far from common across OECD health systems."

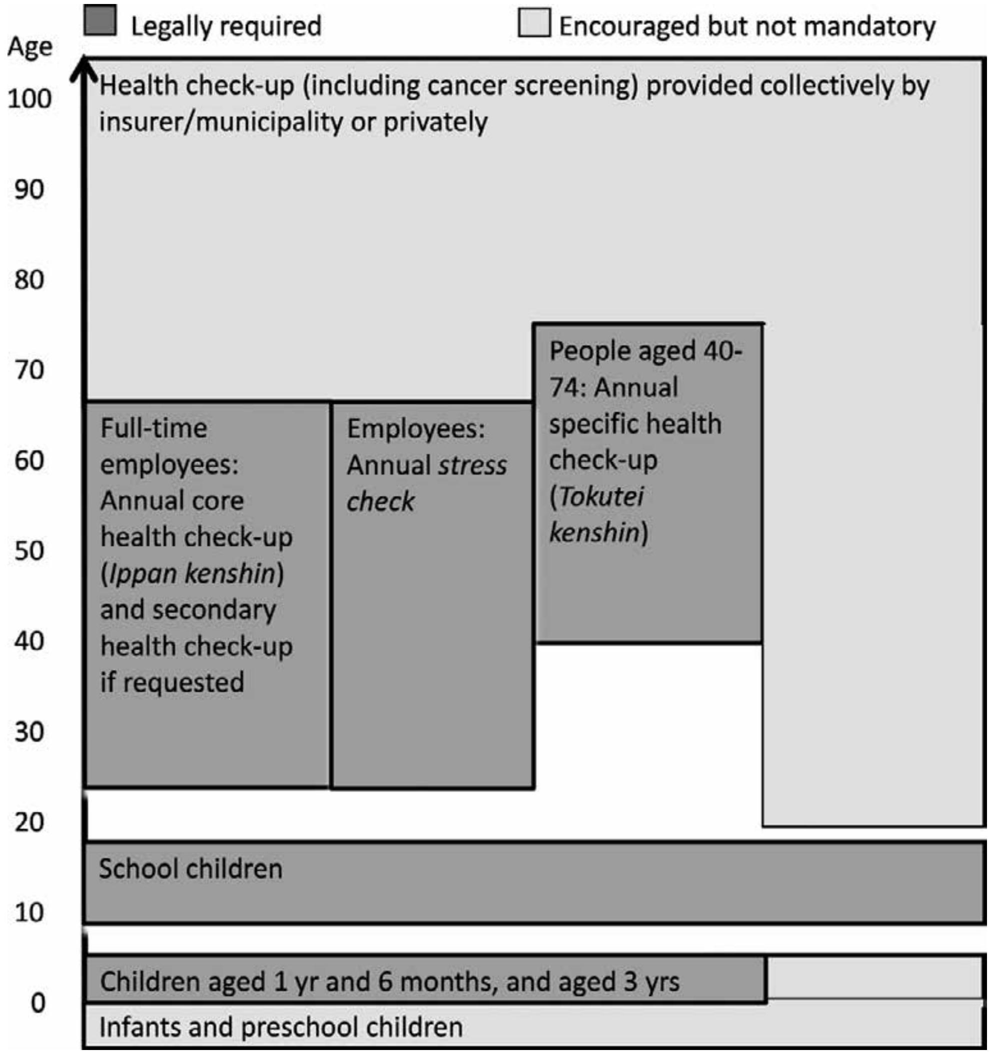
Health checkups are generally not conducted in other OECD countries. In many OECD countries, primary care specialists provide continuous care and carry much of the responsibility for managing the health of their respective populations. Even in countries that do perform health checkups, they are generally not as frequent as those in Japan, and the scope of the items included in the checkup is narrower. Only a small number of OECD countries have obligatory health checkups for workers, but these are less frequent and more targeted than those in Japan. However, in Japan, there are very few primary care physicians who have undergone specialist training. Instead, public health interventions and primary care functions, including health checkups, cancer screening, disease management, and vaccination programs, are provided in an entirely uncoordinated way by local, private practitioners, medical specialists in other fields, occupational health physicians, and public health nurses. For these reasons, it is becoming the norm in Japan for people at high risk of lifestyle-related diseases not to seek or receive the right medical support, despite undergoing health checkups every year. For example, the 2012 'Survey on State of Employees' Health' (Ministry of Health, Labour and Welfare, 2012) revealed that, among people whose health checkup results indicated a need for further testing or medical support, more than a third of those people—and approximately half among those aged 20 to 29—did not undergo any follow-up tests or treatment.

Figure 13 shows that health checkups are available for people across almost all age groups in Japan. While there is a lot of overlap in the content of the various checkups, there are numerous types of health checkup available that are rarely used.

It is difficult to estimate the costs of health checkups because they vary between those subsidized by national government, those that receive limited subsidy, and those conducted independently by municipalities and local governments (Ministry of Health, Labour and Welfare, 2015). For example, in terms of expenditure required for the specific health checkup program, which includes specific health guidance, the government budgeted 22.2 billion yen for FY2021 and 21.1 billion yen for FY2022[1]. However, these figures represent the combined total of the one-third subsidy for national health insurance and the fixed amounts of subsidy to other insurers, and thus the total cost of the specific health checkup program

[1] Improved cost-effectiveness of specific health checkups was also proposed as a MHLW administrative reform in FY2020. https://www.kantei.go.jp/jp/singi/gskaigi/dai41/siryou2.pdf

Figure 13. Health check-ups are available routinely for almost all segment of population in Japan



Source: OECD (2019)

can be expected to be several times greater.

Although it is a legal requirement for companies to provide annual health checkups for full-time workers, secondary (follow-up) checkups for those who are deemed to need them (on the basis of the results of their annual checkup), annual stress checks for workers, and 6-monthly checkups (as a minimum) for designated employees that work in hazardous conditions, it is difficult to estimate the exact costs of these programs because it is the employers that generally bear the expenses involved[2].

[2] Some small businesses receive subsidy from the Industrial Accident Compensation Insurance scheme, but the amount is not large.

The costs of health checkups for preschool children (at 1 year 6 months and at 3 years of age) are borne by local governments, and those for children of school age are borne by their educational establishment, and these are therefore considered to be under the Ministry of Education, Culture, Sports, Science and Technology budget. In this way, health checkup expenditure becomes hidden within wider budgets, making it difficult to make even a basic assessment of cost-effectiveness.

We attempted to estimate the degree to which the financial burden of specific health checkups could be reduced if the program were to be brought into line with those of other countries, namely, by screening only those people whose result was within the normal range in the previous screening, and by performing checkups every three years instead of annually. According to our analysis of BG level data, 89.6% of people would qualify for the next specific health checkup, which suggests it would be possible to reduce the government's financial burden alone by approximately 50 billion yen. The total reduction in health checkup costs would therefore be several times this amount.

Finally, we consider specific policies to resolve over- and under-provision of health care in relation to diabetes treatment.

First, long-term educational hospitalization for diabetes should be regulated[3], and the use of organized DSMES, as recommended by Japanese clinical practice guidelines for diabetes patients, is highly effective. It is therefore necessary to develop and promote out-of-hospital medical care services through community-based initiatives, such as by making better use of internet and smartphone technology.

Second, to solve the problem of under-provision of diabetes care, it is necessary to connect hyperglycemic patients with the right medical services in a more effective way. It is very difficult to change patient behavior using the 'top-down' educational methods that have traditionally been employed. Instead, this role should be carried out by specialists in family medicine, who can take into account the context and background of individual patients and conduct motivational interviewing (Rollnick, 2010), assisted by teams of nurses and nutritionists. However, this model also requires a suitable payment system to support it. To achieve this, it may be a good idea to include elements of results-based payment, such as the Quality and Outcomes Framework (QOF) discussed by Ito and Kassai (2022), and to take inspiration from successful initiatives overseas that reward medical providers when their local communities (registered patients) become healthier. Furthermore, in many countries, the interventions described above are often delivered by nurses and assistant physicians.

Third, in order to create a more organic link between health screening and medical care provision, several important changes to the present system should be considered. A full list of health checkup results for each region should be shared with designated medical institutions (small- and medium-sized hospitals and clinics in that region that cooperate in the training of primary care physicians and are selected on the basis of set evaluation criteria),

[3] Watanabe (2022) found that switching from educational hospitalization to a single-day format of diabetes education (i.e., attending as an outpatient) would reduce medical expenses by 31.4 billion yen per year.

and those designated medical institutions should make contact with people on the list who have screened positive (i.e., for whom an abnormal result was found in their health checkup) and provide further testing, medical care, and guidance as necessary. The health outcomes for those patients at that medical institution should be evaluated after a set interval (e.g., the following year, or in 3-5 years) and then used to determine the additional remuneration that medical institution should receive.

As was noted by the OECD (2019), even though Japan is experiencing unprecedented pressure on its health resources as a result of its rapidly aging population, it has an extensive range of checkups and screenings to improve population health and increase early detection of diseases; however, given the exceptionally high number and high frequency of tests performed in these checkups, there is a danger that they are ineffective, poor value for money, and even harmful.

In order to make the health checkup and screening program more effective, it is necessary to make use of the latest available research evidence to prioritize tests that make a significant contribution to maintaining and improving the nation's health and to set the scope of the checkup contents accordingly, and to implement and evaluate healthcare policies using appropriate indicators, including cost-effectiveness.

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Conflict of interest statement

The authors declare no conflict of interest in this study.

References

American Diabetes Association (ADA) (2021a), "Diabetes overview", *American Diabetes Association*, Available at: http://www.diabetes.org/diabetes (Accessed: September 27, 2022)

American Diabetes Association (ADA) (2021b), "2. Classification and diagnosis of diabetes: Standards of medical care in diabetes-2021", *Diabetes Care*, Vol. 44 No. 1, pp. S15-S33, doi: 10.2337/dc21-S002

Araki, E., A. Goto, T. Kondo, et al. (2020), "Japanese Clinical Practice Guideline for Diabetes 2019", *Diabetology International,* Vol. 11, pp. 165-223, doi: 10.1007/s13340-020-00439-5

Canadian Task Force on Preventive Health Care (CTFPHC) (2012), "Recommendations on screening for type 2 diabetes in adults", *Canadian Medical Association Journal*, Vol. 184 No. 15, pp. 1687-96, doi: 10.1503/cmaj.120732

Centers for Disease Control and Prevention (CDC) (2021), "Diabetes risk factors", *Centers for Disease Control and Prevention,* Available at: https://www.cdc.gov/diabetes/basics/risk-factors.html (Accessed: September 27, 2022)

Dickinson, W.P., L.M. Dickinson, B.T. Jortberg, et al. (2019), "A cluster randomized trial comparing strategies for translating self-management support into primary care practices", *Journal of the American Board of Family Medicine*, Vol. 32 No. 3, pp. 341-352, doi: 10.3122/jabfm.2019.03.180254

Dilla, T., A. Valladares, C. Nicolay, et al. (2012), "Healthcare costs associated with change in body mass index in patients with type 2 diabetes mellitus in Spain: The ECOBIM Study", *Applied Health Economics and Policy*, Vol. 10 No. 6, pp. 417-430, doi: 10.1007/BF03261876

Hanafusa, N., M. Abe, N. Joki, et al. (2021), "2020 Annual Dialysis Data Report, JSDT Renal Data Registry," *Journal of Japanese Society for Dialysis Therapy*, Vol. 54, No. 12, pp. 611-657 (Japanese with English abstract)

He, X., J. Li, B. Wang, et al. (2017), "Diabetes self-management education reduces risk of all-cause mortality in type 2 diabetes patients: a systematic review and meta-analysis", *Endocrine,* Vol. 55, pp. 712-731, doi: 10.1007/s12020-016-1168-2

Ii, M. (2015), "Dai 1-shō: 'Iryō bun'ya no kaikaku no hōkō-sei'", in NIRA (sōgō kenkyū kaihatsu kikō) kenkyū hōkoku-sho: "*Shakai hoshō kaikaku shika michi wa nai - 2025-nendo ni muketa 7tsu no mokuhyō*", Nippon Institute for Research Advancement, pp. 9-26, Available at: https://www.nira.or.jp/pdf/1501report.pdf (Accessed: September 27, 2022) (Japanese)

Ii M. and S. Watanabe (2022) "The paradox of the COVID-19 pandemic: The impact on patient demand in Japanese hospitals," *Health Policy,* Vol. 126, No. 11, pp. 1081-1089

Iizuka, T., K. Nishiyama, B. Chen, et al. (2021), "False alarm? Estimating the marginal value of health signals", *Journal of Public Economics*, Vol. 195, pp. 104368. doi.org/10.1016/

j.jpubeco.2021.104368

International Diabetes Foundation (2020), "About diabetes", *International Diabetes Foundation,* Available at: https://www.idf.org/aboutdiabetes/complications.html (Accessed: September 27, 2022)

IQVIA Institute for Human Data Science (2021), "Global medicine spending and usage trends", Available at: https://heatinformatics.com/sites/default/files/images-videosFileContent/global-medicine-spending-and-usage-trends.pdf (Accessed: September 27, 2022)

Ismail, K., K. Winkley and R. Rabe-Hesketh (2004), "Systematic review and meta-analysis of randomized controlled trials of psychological interventions to improve glycaemic control in patients with type 2 diabetes", *Lancet,* Vol. 363 No. 9421, pp. 1589-1597, doi: 10.1016/S0140-6736(04)16202-8

Ito, Y. and R. Kassai (2023), "Quality indicators for treatment outcomes of regional medical institutions", in M. Ii (ed), "The Reality of Over- and Under-Provision of Health Care in Japan: Financial Impacts", *Public Policy Review*, Vol. 19 No. 1, pp. 1-25.

Japan Diabetes Society (2019), "*Tōnyōbyō shinryō guideline 2019*", Nankodou, available at: http://www.jds.or.jp/modules/publication/index.php?content_id=4 (Accessed: September 27, 2022) (Japanese)

Japan Diabetes Society (2020), "*Tōnyōbyō shiryō gaido 2020-2021*", Kounbundou, Tokyo, (Japanese)

Japan. Ministry of Health, Labour and Welfare (2012), "2012 Rōdōsha kenkō jyōkyō chōsa -Kekka no gaiyō-", *Ministry of Health, Labour and Welfare (online),* Available at: https://www.mhlw.go.jp/toukei/list/h24-46-50.html (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2015), "Dai 1-kai kenkō shinsa-tō senmon iinkai shiryō", *Ministry of Health, Labour and Welfare (online),* Available at: https://www.mhlw.go.jp/file/05-Shingikai-10601000-Daijinkanboukouseikagakuka-Kouseikagakuka/0000104590.pdf (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2018), "Heisei 29 nendo jinkō dōtai tokushu hōkoku, Heisei 27-nen todōfuken betsu nenrei chōsei shibō-ritsu no gaikyō", *Ministry of Health, Labour and Welfare (online)*, Available at: https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/other/15sibou/index.html (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2019), "Heisei 29 nen (2017) kanja chōsa no gaiyō", *Ministry of Health, Labour and Welfare (online),* Available at: https://www.mhlw.go.jp/toukei/saikin/hw/kanja/17/index.html (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2020a), "Heisei 30 nendo kokumin iryōhi no gaikyō", *Ministry of Health, Labour and Welfare (online),* Available at: https://www.mhlw.go.jp/toukei/saikin/hw/k-iryohi/18/index.html (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2020b), "Reiwa gan'nen kokumin kenkō/eiyō chōsa hōkoku", *Ministry of Health, Labour and Welfare (online),* Available at:

https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/kenkou/eiyou/r1-houkoku_00002.html (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2020c), "Tokuteikenshin hoken shidō no iryō-hi tekisei-ka kōka no kenshō no tame no wākingu gurūpu torimatome", *Ministry of Health, Labour and Welfare (online)*, Available at: https://www.mhlw.go.jp/content/12401000/000616588.pdf (Accessed: September 27, 2022) (Japanese)

Japan. Ministry of Health, Labour and Welfare (2021), "Tokutei kenshin·tokutei hoken shidou ni tsuite", *Ministry of Health, Labour and Welfare (online)*, Available at: https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000161103.html (Accessed: September 27, 2022) (Japanese)

JMDC (2021), "JMDC Claims Database", *JMDC*, Available at: https://www.jmdc.co.jp/en/jmdc-claims-database/ (Accessed: September 27, 2022)

Kobori, S., Y. Ichikawa, S. Kodama, et al. (2006), "Evaluation of critical pathway computerization of the educational hospitalization for diabetes mellitus", *Journal of Japan Society for Health Care Managemen*t, Vol. 7, pp. 315-319, (Japanese with English abstract)

Nagashima, M.M., N. Ugihara, H. Fukukawa, et al. (2005), "Comparison of the effect of a four-day and of a two-week educational hospitalization using critical path on the control of diabetes mellitus", *Journal of Japan Society for Health Care Management*, Vol. 5, pp. 487-492, (Japanese with English abstract)

National Institute for Health and Care Excellence (2017), "Type 2 diabetes: prevention in people at high risk", *NICE*, Available at: https://www.nice.org.uk/guidance/ph38/chapter/Recommendations (Accessed: September 27, 2022)

Nawata, K. (2015), "Robust estimation based on the third-moment restriction of the error terms for the Box-Cox transformation model: An estimator consistent under heteroscedasticity", *Economics Bulletin*, Vol. 3 No. 2, pp. 1056-1064, doi: 10.4236/ojs.2016.65069

Nawata, K. (2021a), "An analysis of blood pressure situations in Japan using the large-scale medical checkup dataset", *Health*, Vol. 13, pp. 736-756, doi: 10.4236/health.2021.137057

Nawata, K. (2021b), "Estimation of diabetes prevalence, and evaluation of factors affecting blood glucose levels and use of medications in Japan", *Health*, 13, pp. 1431-1451. doi:10.4236/health.2021.1312102

Nawata, K. and K. Kawabuchi (2015), "Financial sustainability of the Japanese medical payment system: Analysis of the Japanese medical expenditure for educational hospitalization of patients with type 2 diabetes", *Health*, Vol. 7, pp. 1007-1021, doi: 10.4236/health.2015.78118

Nawata, K. and K. Kawabuchi (2016), "Comparison of the length of stay and medical expenditures among Japanese hospitals for type 2 diabetes treatments: The Box-Cox transformation model under heteroscedasticity", *Health*, Vol. 8, pp. 49-63, doi: 10.4236/health.2016.81007

Nawata, K. and M. Kimura (2017), "Evaluation of medical costs of kidney diseases and risk factors in Japan", *Health*, Vol. 9, pp. 1734-1749, doi: 10.4236/health.2017.913127

Nawata, K., Y. Sekizawa and M. Kimura (2018), “Evaluation of blood pressure control medicines using health and medical checkup data in Japan: Alternative methods for randomized controlled trials”, *Health,* Vol. 10, pp. 587-603, doi: 10.4236/health.2018.105047

Nawata, K., M. Ii and R. Kassai (2022), “Tōnyōbyō kenshin ni okeru kajyō to kashō -Iryō shigen no kōritsu riyō ni kansuru kenkyū-”, *Financial Review,* No. 148, pp. 5-34 (Japanese with English abstract)

Nelson, L.A., S.E. Williamson, A. Nigg, et al. (2020), “Implementation of technology-delivered diabetes self-care interventions in clinical care: A narrative review”, *Current Diabetes Report*, Vol. 20 No. 12, p.71, doi: 10.1007/s11892-020-01356-2

Norris, S.L., P.J. Nichols, C.J. Caspersen, et al. (2002), “Increasing diabetes self-management education in community settings: A systematic review”, *American Journal of Preventive Medicine*, Vol. 22 (Suppl. 4), pp. 39-66, doi: 10.1016/s0749-3797(02)00424-5

Organisation for Economic Co-operation and Development (2019), “*OECD Reviews of Public Health: Japan: A Healthier Tomorrow*”, OECD Publishing, Available at: https://www.oecd.org/japan/oecd-reviews-of-public-health-japan-9789264311602-en.htm (Accessed: September 27, 2022)

Pillay, J., M.J. Armstrong, S. Butalia, et al. (2015a), “Behavioral programs for type 1 diabetes mellitus: A systematic review and network meta-analysis”, *Annals of Internal Medicine,* Vol. 163 No. 11, pp. 836-847, doi: 10.7326/M15-1400

Pillay, J., M.J. Armstrong, S. Butalia, et al. (2015b), “Behavioral programs for type 2 diabetes mellitus: A systematic review and network meta-analysis”, *Annals of Internal Medicine,* Vol. 163 No. 11, pp. 848-860, doi: 10.7326/M15-1400

Powers M.A., J. Bardsley, M. Cypress, et al. (2015), “Diabetes self-management education and support in type 2 diabetes: A joint position statement of the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics”, *Diabetes Care*, Vol. 38 No. 7, pp. 1372-1382, doi: 10.2337/diaclin.34.2.70

Rollnick, S., C.C. Butler, P. Kinnersley, et al. (2020), “Motivational interviewing”, *BMJ,* Vol. 340, c1900, doi: 10.1136/bmj.c1900

Slade, A.N. (2012), “Health investment decisions in response to diabetes information in older Americans”, *Journal of Health Economics*, Vol. 31 No. 3, pp. 502-520, doi: 10.1016/j.jhealeco.2012.04.001

Statistics Bureau of Japan (2020), “Jinkō tōkei, 1 October, 2019 -Zenkoku: nenrei (kakusai), danjyobetsu jinkō todōfuken: nenrei (5sai kaikyū), danjyobetsu jinkō-”, *E-Stat,* Available at: https://www.stat.go.jp/data/jinsui/2019np/index.html (Accessed: September 27, 2022) (Japanese)

Tsurumi, K. (2002), “(6) Eiyō shokuji shidō to kuritikarupasu: Tōnyō-byō kyōiku nyūin no kuritikarupasu no seika to kadai”, *Japanese Journal of National Medical Services*, Vol. 56, pp. 160-161 (Japanese)

US Preventive Services Task Force (USPSTF) (2021), “Screening for prediabetes and type 2 diabetes: US Preventive Services Task Force recommendation statement”, *Journal of American Medical Association,* Vol. 326 No. 8, pp. 736-743, doi: 10.1001/jama.2021.12531

Watanabe, S. (2022), “Nawata/Ii/Kassai ronbun ni taisuru komento”, *Financial Review*, Vol. 148, pp. 35-37. (Japanese)

Wilke, T., A. Groth, S. Mueller, et al. (2013), “How to use pharmacy claims data to measure patient nonadherence? The example of oral diabetics in therapy of type 2 diabetes mellitus”, *European Journal of Health Economics,* Vol. 14 No. 3, pp. 551-568, doi: 10.1007/s10198-012-0410-y

World Health Organization (2020), “World health statistics 2020: Monitoring health for the SDGs, sustainable development goals”, *World Health Organization*, Available at: https://apps.who.int/iris/handle/10665/332070 (Accessed: September 27, 2022)

World Health Organization (2021), “Diabetes”, *World Health Organization,* Available at: https://www.who.int/news-room/fact-sheets/detail/diabetes (Accessed: September 27, 2022)

Yamamoto, M., Y. Takeuchi and H. Ichiwaka (2000), “A critical-path of educational program for diabetic inpatient”, *Journal of Japan Society for Health Care Management,* Vol. 1, pp. 130-133 (Japanese with English abstract)