

Impacts of the 2016 Kumamoto Earthquake on glycemic control in patients with diabetes

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Keywords

Diabetes, Earthquake, Glycemic control

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J Diabetes Investig 2019; 10: 521–530

doi:10.1111/jdi.12891

Clinical Trial Registry

University Medical Hospital Information Network

UMIN000024757

ABSTRACT

Aims/Introduction: On April 14 and 16 2016, the Kumamoto area was severely damaged by several massive magnitude 7 class earthquakes.

Materials and Methods: To examine the effects of these earthquakes on glycemic control and stress factors, glycosylated hemoglobin, glycosylated albumin, other biochemical parameters, a self-administered lifestyle-associated questionnaire and disaster-associated stress scores were analyzed. A total of 557 patients with diabetes were enrolled, and data were collected at 13 months before to 13 months after the earthquakes.

Results: In patients with type 1 diabetes and specific types of diabetes due to other causes, glycemic control was not altered during the observational period. This glycemic stability in type 1 diabetes might result from self-management of insulin doses. In patients with type 2 diabetes, glycosylated hemoglobin decreased by 0.11% (from 7.33 to 7.22%) at 1–2 months after the earthquakes, and increased thereafter. The reduction of glycosylated hemoglobin after 1–2 months in type 2 diabetes was associated with 'early restoration of lifelines' and 'sufficient sleep.' The glycemic deterioration at a later stage was related to 'shortage of antidiabetic agents,' 'insufficient amount of food,' 'largely destroyed houses' and 'changes in working environments.' Disaster-associated stress levels were positively correlated with 'age,' 'delayed restoration of lifelines,' 'self-management of antidiabetic agents' and 'increased amount of physical activity/exercise,' and negatively associated with 'early restoration of lifelines' and 'sufficient sleep.'

Conclusions: Glycemic control, associated factors and stress levels are altered in chronological order. Post-disaster diabetic medical care must consider these corresponding points in accordance with the time-period.

INTRODUCTION

In April 2016, the Kumamoto area located on the island of Kyushu, southwest Japan, was severely damaged by several massive earthquakes. A magnitude (M) 7.3 on the Richter scale mainshock occurred on April 16 2016, close to the epicenter of an M 6.5 foreshock that occurred approximately 28 h earlier (Figure 1)¹. These two huge earthquake sequences generated severe shaking, and caused extensive destruction in central Kyushu. The earthquakes caused 50 casualties, and >7,000 buildings were severely damaged. The epicenters of the two major earthquakes were located in the western part of the Mashiki Town, and Kumamoto University Hospital is mapped approximately 10 km west from the epicenters (Figure 1).

Previous reports have shown that, after a natural disaster, glycemic control in patients with diabetes deteriorates^{2–9}. Such worsening of glycemic control can be explained by inadequate food intake^{6,9}. It has also been proposed that post-disaster glycemic control alterations vary among individual patients⁷. Glycemic control in patients with diabetes after the 1995 Hanshin-Awaji earthquake in Japan significantly deteriorated in the Kobe area, but not in the Osaka area³. In 2011, the Great East Japan Earthquake struck the Tohoku area in Japan, and glycosylated hemoglobin (HbA1c) in patients with type 1 diabetes involved in the earthquake became 0.26% higher, indicating that patients with a lower insulin secretory capacity might be more vulnerable to stressful conditions⁷. The stressful conditions provoked by prolonged aftershocks, long-term shelter life and/or spending nights in a car were problematic after the Kumamoto

Received 7 May 2018; revised 19 June 2018; accepted 3 July 2018

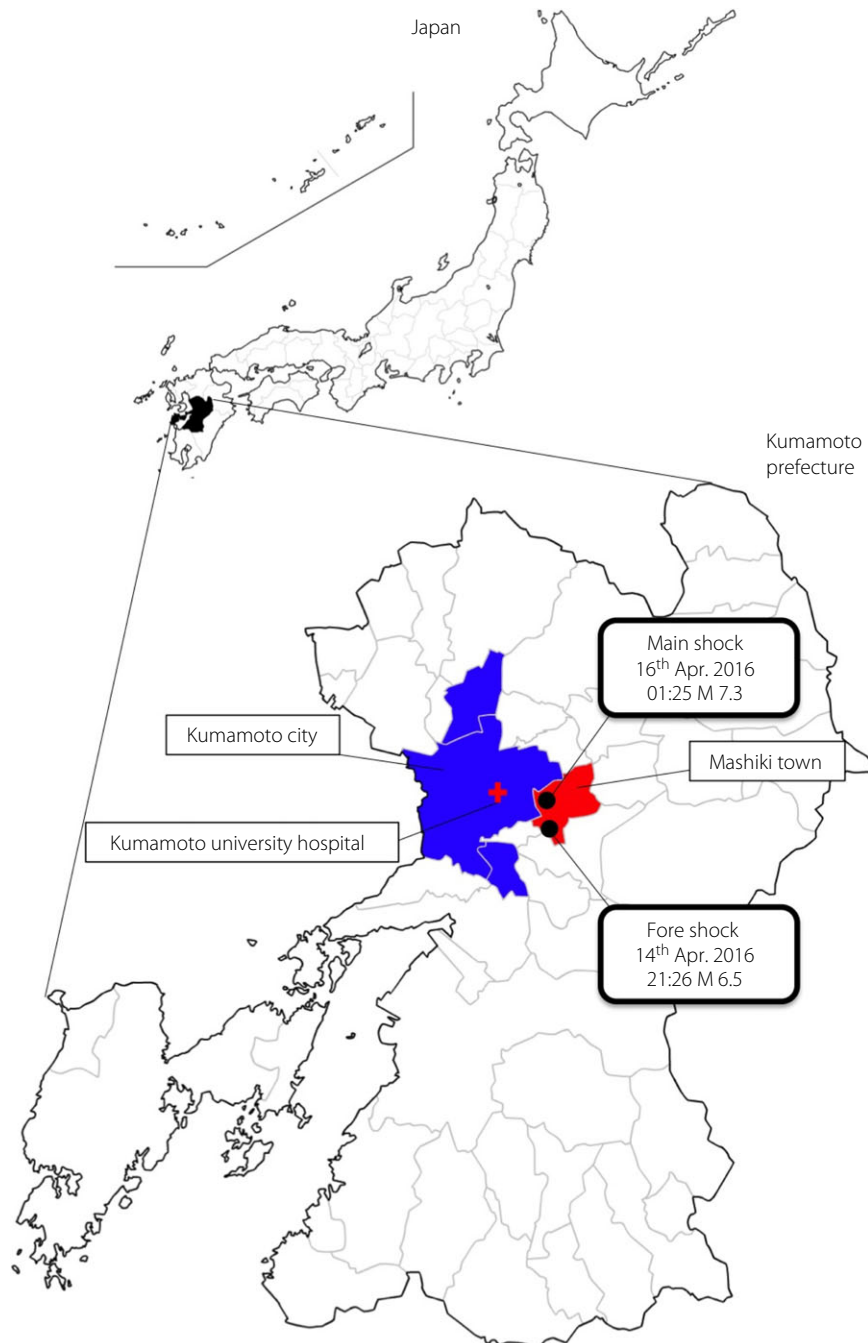


Figure 1 | The geographical location of Kumamoto University Hospital and the epicenters. Closed circles indicate the epicenters. A cross sign indicates the location of Kumamoto University Hospital approximately 10 km west of the epicenters.

earthquakes. To identify the association between lifestyle alterations, stress levels and glycemic changes in patients with diabetes affected by the Kumamoto earthquakes, we examined the alterations in metabolic parameters, physical examinations and biochemical data. In addition, we carried out questionnaire surveys of the study participants regarding earthquake-related damage and post-earthquake lifestyle alterations, as well as

identifying traumatic stress scores using the Impact of Event Scale-Revised (IES-R).

METHODS

Study population

The present study was approved by the ethics committee of Kumamoto University Hospital (Ethics No. 1170), and was

carried out in line with the ethical rules of the Declaration of Helsinki in 1995. The observational research was registered with an approved International Committee of Medical Journal Editors clinical trial registry, University Medical Hospital Information Network (ID: UMIN000024757), and the date of registration is 8 November 2016. We carefully obtained informed consent as well as questionnaire responses from individual patients attending doctors for their mental burden. As a result, there were no rejections in the participation of this study, and no problems associated with mental burden.

To identify potential association markers, we collected data on several metabolic parameters, including glycemic control indexes, such as HbA1c, glycated albumin (GA) and random plasma glucose, from 727 outpatients with diabetes who had been regularly followed up at Kumamoto University Hospital, Kumamoto, Japan. To minimize other possible influential factors, exclusion criteria were specified as follows: thyroid dysfunction (71 patients), active hepatic disease (22 patients), pregnancy (excluded at recruitment), taking medication that affects glucose levels (excluded at recruitment), regular follow-up period of <12 months (73 patients) and living outside Kumamoto prefecture at the time of the earthquakes (four patients). After a total of 170 exclusions, 557 patients were considered to be eligible for the analysis.

Study design

We examined the parameters in these patients 1–2, 3–4, 6–7 and 12–13 months before, and 1–2, 3–4, 6–7 and 12–

13 months after the 2016 Kumamoto earthquakes. We carried out a questionnaire survey of the study participants regarding earthquake-related damage and post-earthquake lifestyle alterations. Post-traumatic mental stress levels were assessed using the IES-R score¹⁰.

Laboratory and physical examinations

Observational acquisition of data, such as the type of diabetes, diabetes history, bodyweight, systolic and diastolic blood pressure, heart rate, and biochemical parameters including random blood glucose, HbA1c, GA, immune reactive insulin, C-peptide, urinary albumin excretion, aspartate transaminase, alanine transaminase, lactate dehydrogenase, blood urea nitrogen, creatinine, estimated glomerular filtration rate, uric acid, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglyceride, total cholesterol, white blood cells, red blood cells, hemoglobin, platelets and hematocrit was carried out.

Statistical analysis

Continuous variables were expressed as average \pm standard deviation, and categorical variables were expressed as percentages. Pre- and post-glycemic control were assessed by mixed model statistics.

RESULTS

Baseline characteristics of eligible participants in the study

The baseline characteristics of the participants in the present study are shown in Table 1. A total of 55 patients with type

Table 1 | Clinical characteristics of 557 participants before the earthquakes

	Type 1 diabetes	Type 2 diabetes	Others
<i>n</i>	55	449	53
Age (years)	51.2 \pm 16.4	63.4 \pm 11.9 [‡]	59.3 \pm 12.7
Male/female	20/35	239/210	20/33
BMI	22.2 \pm 3.7	25.4 \pm 4.8	23.9 \pm 4.8
Diabetes history (years)	20.0 \pm 9.8	14.6 \pm 9.5	9.1 \pm 7.2**
Blood glucose (mg/dL)	177.4 \pm 72.3	150.9 \pm 47.3	135.4 \pm 49.9
HbA1c (%)	8.23 \pm 1.54*	7.26 \pm 1.07	7.08 \pm 1.28
GA (%)	26.6 \pm 7.3	18.6 \pm 3.8	19.4 \pm 6.7
SBP (mmHg)	121.0 \pm 16.5	128.6 \pm 17.1	124.9 \pm 16.0
DBP (mmHg)	67.5 \pm 13.2	72.6 \pm 11.8	72.8 \pm 11.8
HR (b.p.m)	76.8 \pm 12.0	77.7 \pm 12.2	79.2 \pm 13.4
Retinopathy	36.60%	29.40%	20.50%
Nephropathy	28.20%	35.6% [§]	22.50%
Neuropathy	34.30%	34.20%	20.30%
OHA	15.50%	81.6% [‡]	55.40%
Insulin	98.6% [†]	33.80%	59.5% ^{††}
GLP-1RA	0%	10.0% [‡]	5.40%

Data are presented as means or ratio (%). The Fisher's exact test with Bonferroni correction were carried out. * P = 0.002 type 1 diabetes vs type 2 diabetes. [†] P < 0.001 type 1 diabetes vs type 2 diabetes or specific types of diabetes due to other causes (Others). [‡] P < 0.001 type 2 diabetes vs type 1 diabetes or Others. [§] P = 0.037 type 2 diabetes vs Others. ** P < 0.001 Others vs type 1 diabetes or type 2 diabetes. ^{††} P < 0.001 Others vs type 2 diabetes. DBP, diastolic blood pressure; GA, glycated albumin; GLP-1RA, glucagon like peptide-1 receptor agonist; HbA1c, glycated hemoglobin; HR, heart rate; OHA, oral hypoglycemic agents; SBP, systolic blood pressure.

1 diabetes, 449 with type 2 diabetes and 53 with specific types of diabetes due to other causes (Others) were enrolled and their data collected. The mean age of type 2 diabetes patients (63.4 ± 11.9 years) was significantly higher than that of type 1 diabetes patients (51.2 ± 16.4 years) or Others (59.3 ± 12.7 years). The sex ratio was comparable among groups. The duration of diabetes history was shorter in Others (9.1 ± 7.2 years) than that in type 1 diabetes patients (20.0 ± 9.8 years) or type 2 diabetes (14.6 ± 9.5 years). The mean HbA1c in type 1 diabetes patients ($8.23 \pm 1.54\%$) was significantly higher than that of type 2 diabetes ($7.26 \pm 1.07\%$) or Others ($7.08 \pm 1.28\%$). The baseline physical examinations, such as blood pressure and heart rate, were indistinguishable among the groups. The prevalence of diabetic nephropathy was significantly higher in type 2 diabetes patients (35.6%) than in type 1 diabetes patients (28.2%) or Others (22.5%). The presence of retinopathy and neuropathy was not different among the groups. In terms of medications, oral hypoglycemic agents were predominantly prescribed for type 2 diabetes patients (81.6%). The ratio of insulin treatment in type 1 diabetes patients was the highest at 98.6%, compared with 33.8 and 59.6% in type 2 diabetes patients and Others, respectively.

Comparison of pre- and post-earthquake glycemetic parameters

Physical examinations, such as bodyweight, systolic blood pressure, diastolic blood pressure and heart rate, were not altered during the observational period. Blood glucose levels at random sampling were not significantly altered after the earthquakes compared with those before the earthquakes in all types of diabetes (type 1 diabetes 181.2 ± 66.3 mg/dL, type 2 diabetes 148.9 ± 45.0 mg/dL, Others 142.9 ± 62.1 mg/dL at 1–2 months after the earthquakes). In type 1 diabetes patients and Others, HbA1c and GA levels during the study period were unchanged. In type 2 diabetes patients, HbA1c first declined by 0.11% (from 7.33 to 7.22%) at 1–2 months after the earthquakes compared with that before the earthquakes, and increased at 3–4, 6–7 and 12–13 months after the earthquakes. GA levels showed a similar trend in type 2 diabetes patients (Figure 2). As >80% of the patients in the present study had type 2 diabetes, the trend in HbA1c alterations in across all participants was quite similar to that seen in type 2 diabetes patients (Figure 2). The correlation between delta bodyweight and delta HbA1c was not significant ($P = 0.089$) in the present study. There were no significant alterations in other biochemical parameters (data not shown).

Results of the self-administered lifestyle-associated questionnaire at 1 month after the earthquakes

All eligible study participants were living in the Kumamoto area at the time of the earthquakes.

The results of the life management component of the questionnaire are shown in Table 2.

Evacuation

After the foreshock, 4.69% of the patients were evacuated to shelters nearby and 10.65% of those were staying in their cars at the time of the mainshock that occurred at 01.25 hours on 16 April. After the mainshock, the percentage of patients staying in shelters or spending nights in their cars became 26.14 and 47.46%, respectively. The average period of shelter use was 11.73 days for type 1 diabetes patients, 13.72 days for type 2 diabetes patients and 8.90 days for Others. The average period of time staying in their car was 5.17 days for type 1 diabetes patients, 6.57 days for type 2 diabetes patients and 5.19 days for Others.

House damage

More than 60% of the patients experienced house damage, ranging from partially damaged to totally destroyed. In particular, the ratio of 'partially damaged' for type 2 diabetes patients was significantly higher than that of type 1 diabetes patients ($P = 0.037$).

Lifelines

More than 50% of the patients experienced lifeline recovery within 1 week; however, 20% of the patients suffered from disruption of lifelines for >2 weeks.

Food supply during the first month after the earthquakes

More than 50% of the patients struggled to access the appropriate amount and right balance of food. In particular, unbalanced meals were observed in 37.34% ($n = 202$) of all patients.

Water supply

Approximately 20% of the patients experienced a shortage of water supply.

Amount of physical activity/exercise during the first month after the earthquakes

Approximately 50% of the patients reported that the amount of physical activity/exercise did not change. One-third of the patients experienced a reduced amount of physical activity/exercise. These results were consistent with the data that the number of patients with type 1 diabetes who reduced their insulin doses (20.00%) was higher than those who increased their insulin doses (7.27%).

Amount of sleep during the first month after the earthquakes

Three-quarters of the patients experienced some kind of sleep disturbance.

Changes in family environment

A total of 76 patients (13.8%) experienced changes in their family environment.

Changes in working environment

A total of 98 patients (18.2%) experienced changes in their working environment.

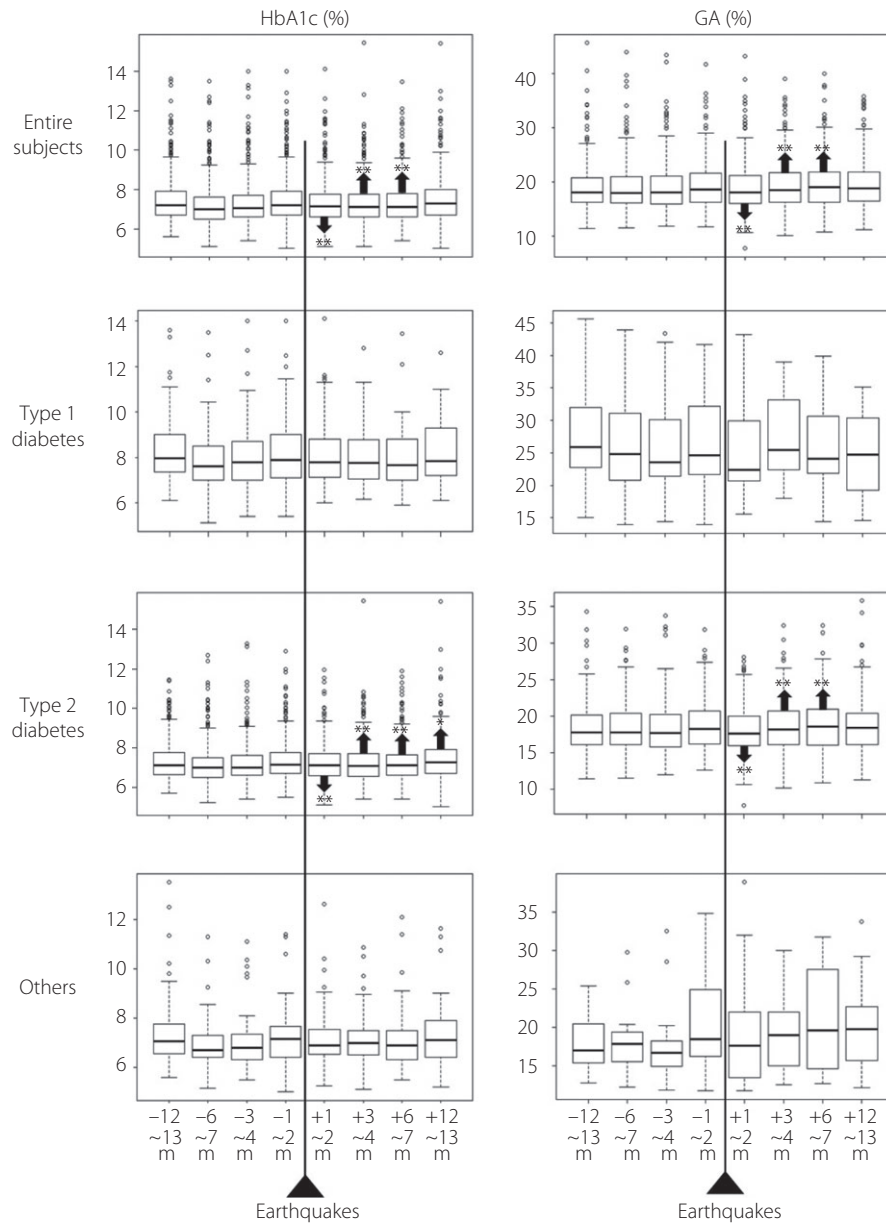


Figure 2 | Chronological alterations in glycated hemoglobin (HbA1c) and glycated albumin (GA) in all patients, type 1 diabetes patients, type 2 diabetes patients and patients with diabetes due to other causes (Others). The median, first and third quartiles of HbA1c and GA are expressed in a box plot. The statistical analysis was carried out using a mixed model. * $P < 0.05$, ** $P < 0.01$ compared with the corresponding values before the earthquake.

Changes in family members' working environments

A total of 87 patients (16.11%) experienced changes in a family member's working environment.

Bereavement

A total of 20 patients (3.64%) experienced bereavement.

The results of the medical care management component of the questionnaire are shown in Table 3.

Insufficiency of antidiabetic agents

Just 5.6% of the patients complained of an insufficiency of antidiabetic agents. That insufficiency was mainly observed in central (7.0%) and eastern (12.2%) areas of Kumamoto City, but not in Mashiki Town (0%), where the epicenters were located. Just 2.11% of the patients ($n = 8$) were prescribed antidiabetic agents by other hospitals or at the shelters.

Table 2 | Results of self-administered lifestyle-associated questionnaire at 1 month after the earthquakes (life management)

	Total, %	Type 1 diabetes, %	Type 2 diabetes, %	Others, %
1) Evacuation after foreshock				
In shelters	4.69	5.56	4.91	1.92
In their cars	10.65	14.81	10.49	7.69
1) Shelter use after mainshock	26.13	28.30	26.74	18.87
1) Spend nights in their cars after mainshock	47.46	11.73 days 54.55 5.17 days	13.72 days 47.07 6.57 days	8.90 days 43.40 5.91 days
2) House damage				
No damage	38.38	45.45	34.90	60.38
Partially damaged	43.60	30.91	46.53*	32.08
Half destroyed	10.27	14.55	10.51	3.77
Largely destroyed	4.32	7.27	4.25	1.89
Totally destroyed	3.42	1.82	3.80	1.89
3) Lifelines				
Recovered within 1 week	55.27	59.26	54.92	54.00
Recovered in 1–2 weeks	24.58	20.37	24.49	30.00
Recovered in 2–4 weeks	14.60	18.52	14.42	12.00
Recovered more than 4 weeks	5.55	1.85	6.18	4.00
4) Food supply				
As usual	46.95	36.54	48.75	42.00
Insufficient	9.06	11.54	8.88	8.00
Unbalanced	37.34	50.00	35.31	42.00
NA	6.65	1.92	7.06	8.00
5) Water supply				
Sufficient	83.84	90.91	82.41	88.68
Insufficient	16.16	9.09	17.59	11.32
6) The amount of physical activity/exercise				
No change	53.60	50.91	53.90	53.85
Reduced	36.69	34.55	37.42	32.69
Increased	9.71	14.55	8.69	13.46
7) The amount of sleep				
Sufficient	23.15	12.73	24.66	21.15
Fair enough	35.80	32.73	34.75	48.08
Not enough	31.83	43.64	31.61	21.15
Insomnia	9.22	10.91	8.97	9.62
8) Changes in family environment				
Yes	13.79	14.81	14.19	9.43
No	86.21	85.19	85.81	90.57
9) Changes in their working environment				
Yes	18.25	18.87	18.01	19.61
No	81.75	81.13	79.95	80.39
10) Changes in a family member's working environment				
Yes	16.11	9.09	17.78	9.62
No	83.89	90.91	82.22	90.38
11) Bereavement	3.64	3.64	4.07	0.00

Data are expressed as ratio (%) unless otherwise indicated. * $P = 0.037$ vs type 1 diabetes. NA, not available, Others, specific types of diabetes due to other causes.

Visit

Regular visits to our hospital were disturbed in the chaotic situation, thus 42.9% of the patients changed their original appointment date, mostly extended. Just 1.9% of the patients with type 2 diabetes visited earlier than their scheduled appointment date.

Self-monitoring of blood glucose

A total of 15 patients (3.2%) lost their personal self-monitoring of blood glucose devices. Insufficiency of a glucose-monitoring sensor was observed in 5.56% ($n = 26$) in total (15.38% in type 1 diabetes patients [$n = 6$], 4.11% in type 2 diabetes patients [$n = 16$] and 10.0% in Others [$n = 4$]), and was significantly

Table 3 | Results of self-administered lifestyle associated questionnaire at 1 month after the earthquakes (medical care management)

	Total, %	Type 1 diabetes, %	Type 2 diabetes, %	Others, %
12) The insufficiency of antidiabetic agents	5.60	7.27	5.09	8.16
13) Irregular visits to the hospital	42.89	35.14	43.35	48.15
13) How many days prescriptions at 1st visit		36.71 days	42.96 days	37.64 days
13) Prescriptions from other hospitals	2.11	2.70	1.90	3.70
14) Glucose monitoring				
Lost personal SMBG device	3.21	10.26	2.57	2.50
Insufficiency of SMBG sensor	5.56	15.38*	4.11	10.00
Insufficiency of SMBG lancet	3.63	5.13	3.08	7.50
Insufficiency of replenishing glucose	2.14	10.26 [†]	1.29	2.50
Insufficiency of cotton swab	3.42	5.13	2.57	10.00
Use of different SMBG device	1.12	1.82	1.16	0.00
Reductions in the frequency of glucose monitoring	5.79	9.09	5.09	8.33
Increases in the frequency of glucose monitoring	2.43	7.27	2.08	0.00
No glucose monitoring	8.04	10.91	7.64	8.33
Increased incidence of hypoglycemia	2.62	7.27	2.08	2.08
Decreased incidence of hypoglycemia	1.50	7.27	0.93	0.00
Reuse of insulin injection needles	1.68	7.27 [‡]	1.16	0.00
Insulin dose reduction in insulin users	3.55	20.00 [§]	4.30	3.10
Insulin dose increase in insulin users	1.68	7.27	2.10	0.00
15) Remedy				
No alterarions	89.34	75.93 ^{¶††}	90.87	90.38
Cessation on self-judgment	2.21	0.00	2.51	1.92
Alterations on self-judgment	3.49	27.27 ^{¶††}	0.68	1.92
Alterations on consulting a doctor	5.51	1.85	5.94	5.77
Lost prescription record book (Okusuri-techou)	13.79	20.00	13.29	11.54
16) The acquisition of medical information				
Not obtained	90.33	94.44	89.38	94.12
Obtained	9.67	5.56	10.62	5.88
16) The source of the medical information				
TV/radio	69.52	74.07	67.90	78.43
Newspapers	31.78	27.78	31.18	41.18
Cell phones (including e-mail/SMS)	20.63	31.48	20.09	13.73
Personal computers	12.83	20.37	11.78	13.73
Japan Diabetes Society website	0.37	0.00	0.23	1.96
Medical consultant	0.56	0.00	0.69	0.00
Others	9.48	9.26	9.24	11.76

Data are expressed as ratio (%) unless otherwise indicated. * $P = 0.029$ vs type 2 diabetes; [†] $P = 0.016$ vs type 2 diabetes; [‡] $P = 0.04$ vs type 2 diabetes; [§] $P = 0.003$ vs type 2 diabetes; [¶] $P < 0.001$ vs type 2 diabetes; ^{††} $P = 0.006$ vs specific types of diabetes due to other causes (Others).

higher in type 1 diabetes patients ($P = 0.029$) compared with type 2 diabetes patients. In contrast, a shortage of lancets for self-monitoring of blood glucose was just 3.8% ($n = 17$) in total. Insufficiency of replenishing glucose was observed in 10.3% ($n = 4$) in type 1 diabetes patients, 1.3% ($n = 5$) in type 2 diabetes patients and 2.5% ($n = 1$) in Others, with a higher incidence in type 1 diabetes patients ($P = 0.016$). Increased incidence of hypoglycemia was observed in 2.62% of patients ($n = 14$), and decreased incidence of hypoglycemia was observed in 1.50% of patients ($n = 8$), without differences among the groups, showing that hypoglycemia was appropriately avoided in the majority of patients. The reuse of insulin injection needles was significantly higher in type 1 diabetes

patients (7.27%, $n = 4$, $P = 0.04$) compared with that in type 2 diabetes patients (1.16%, $n = 5$).

When limited to the insulin users, the ratio of patients with type 1 diabetes who reduced their insulin dose was 20.0% ($n = 11$, $P = 0.003$ vs type 2 diabetes patients). In type 2 diabetes patients it was 4.3% ($n = 6$), and in Others it was 3.1% ($n = 1$). The ratio of patients who increased their insulin dose was 7.27% ($n = 4$, $P = 0.29$ vs type 2 diabetes patients) in patients with type 1 diabetes, 2.1% ($n = 3$) in patients with type 2 diabetes and 0% in Others. According to these results, insulin users with type 1 diabetes successfully managed to control their glycemic control by modulating insulin dosages according to their own judgment.

Remedy

Nearly 90% of the patients did not need to change their treatment regimen. A total of 76 patients (13.79%) lost their prescription record notebook (Okusuri-techou).

Medical information

It is surprising that >90% of the patients were not able to obtain any kind of medical information at the time of the earthquakes. Medical information was provided mainly by TV/radio (69.52%). Patients with type 1 diabetes showed relatively higher rates of obtaining medical information through cell phones (including e-mails and/or social network services) and/or personal computers.

IES-R for post-traumatic stress disorder scale and associated factors

The present research used the IES-R) for measuring post-traumatic stress disorder levels. IES-R is a self-administered questionnaire to score the extent of post-traumatic stress disorder in a wide variety of disasters, identifying stress levels in cross-sectional studies, observational follow up and screening¹⁰. The mean IES-R score across all patients in the study was 11.75 (11.35 in type 1 diabetes patients, 12.11 in type 2 diabetes patients and 9.18 in Others), without differences among the types of diabetes. The scores were significantly higher in the central (mean 14.73, median 9.00, $P < 0.001$) and eastern (mean 13.66, median 9.50, $P = 0.026$) parts of Kumamoto City compared with those in other areas, apart from in Mashiki (mean 22.83, median 14.50, $P = 1.00$) where the epicenters were located.

Multiple regression analysis was carried out to identify the association between the severity of earthquake damage and IES-R scores. IES-R scores were positively correlated with age. IES-R was negatively correlated with recovery of lifelines within 1 week or no suspension. The longer the recovery of lifelines, the higher the regression coefficient, indicating that the impact on IES-R was associated with the recovery status of lifelines. IES-R was also positively correlated with an increased amount of physical activity/exercise, and was negatively correlated with the amount of sleep. IES-R score was also positively correlated with the location where the patients lived, especially for with those that lived in Mashiki.

The multiple regression analysis was again carried out in type 2 diabetes patients – the majority of the study population (449 / 557 = 80.6%) in this research. The IES-R score was positively correlated with age. IES-R was negatively correlated with recovery of lifelines within 1 week or no suspension. A longer lifeline recovery was associated with higher IES-R scores. The insufficiency of antidiabetic agents was observed only in 5.6% of patients, but IES-R score was positively correlated with this insufficiency. IES-R was positively correlated with an increased amount of physical activity/exercise, and was negatively correlated with the amount of sleep.

Glycemic parameters and associated factors

In type 2 diabetes patients, HbA1c and GA first declined at 1–2 months after the earthquakes and increased thereafter (Figure 2). Therefore, multiple regression analysis was carried out to identify the association between the severity of earthquake damage and glycemic parameters in type 2 diabetes patients. At 1–2 months after the earthquakes, HbA1c levels were negatively correlated with lifeline recovery within 2 weeks and sufficient sleep. GA levels were negatively correlated with shelter life and alterations in remedy on consulting a doctor. At 3–4 months after the earthquakes, HbA1c and GA levels were positively correlated with the insufficiency of antidiabetic agents and insufficient food supply. At 6–7 months after the earthquakes, no significant factor was detected in the association of HbA1c levels. GA levels were positively correlated with largely destroyed house damage. At 12–13 months after the earthquakes, HbA1c levels were positively correlated with largely destroyed house damage, the insufficiency of antidiabetic agents and changes in working environment. Increased HbA1c was observed in the patients with type 2 diabetes who experienced largely and totally destroyed houses (+0.243%) compared with that in no damage (+0.044%) at 12–13 months after the earthquakes ($P = 0.013$). GA levels were positively correlated with largely destroyed house damage, insufficient food supply and changes in working environment.

DISCUSSION

An observational study on glycemic control in patients with diabetes associated with the 2016 Kumamoto Earthquakes was carried out. In type 1 diabetes patients and Others, HbA1c and GA levels during the study period were unchanged. In type 2 diabetes patients, HbA1c levels first declined by 0.11% (from 7.33 to 7.22%) at 1–2 months after the earthquakes and increased thereafter. GA levels showed a similar trend in type 2 diabetes patients.

In Japan, a number of huge earthquakes struck around Kobe in 1995, Chuetsu in 2004 and Tohoku in 2011.

The Great Hanshin-Awaji Earthquake occurred on 17 January 1995 in Kobe. The magnitude of the earthquake was 7.2, >6,200 people were killed, and 250,000 people lost their houses due to collapse and/or fire. HbA1c levels were aggravated in the Kobe area (+0.20%. M 7.2), but not in the Osaka area (–0.02%. M 4.2)³. Increased HbA1c and high scores for stress levels were evident in patients with diabetes who experienced severe damage to houses and/or whose relatives had been killed or injured³. Other research highlighted that HbA1c in patients with diabetes was elevated from 7.74 to 8.34% (+0.60%), and this was highly correlated with inappropriate diet⁶.

On 23 October 2004, a major M 6.8 earthquake struck the Chuetsu district of Niigata Prefecture, Japan. In this restricted area, HbA1c in patients with type 1 diabetes had deteriorated at 3 months after the shock (+0.3%), was highest at 5 months (+0.4%) and high HbA1c levels continued until 12 months (+0.3%)⁵.

In 2011, the Great East Japan Earthquake of M 9.0 struck the Tohoku area of Japan. The impact of the earthquake and subsequent Tsunami resulted in >15,000 casualties and 3,000 missing persons. Tohoku University reported that HbA1c in patients with diabetes was maintained at 1 month (7.3 vs 7.3%), but was significantly decreased at 3 months (−0.1%) after the earthquake⁸. In contrast, HbA1c in patients with type 1 diabetes became worse with +0.26% (7.81 vs 8.07%), indicating that patients with a lower insulin secretory capacity might be more vulnerable to stressful conditions⁴. Indeed, fasting C-peptide levels were significantly lower in the patients with worsened glycemic control⁷.

In response to the Great East Japan Earthquake 2011, the Japan Diabetes Society published a book titled *Diabetes Treatment Manual in the Situation of Disaster* in 2014. In this text, it is recommended that a 'DiaMAT: Diabetes Medical Assistance Team' should be established in advance. Furthermore, the American Diabetes Association also emphasizes preparedness against disasters¹¹.

However, we did not have such a team at the time of the 2016 Kumamoto earthquakes. Thus, 1 week after the earthquakes we formed a team, named the 'KDAT: Kumamoto Diabetes medical Assistant Team' with the cooperation of the Japan Diabetes Society, Japanese Association for Diabetes Education and Care, and Japan Council for Promotion of Countermeasures against Diabetes. For 5 weeks after its establishment, our KDAT team visited 14 shelters mainly in Mashiki, where the damage was the most severe. A total of 229 volunteers contributed to the KDAT activity and provided care for 664 people to help measure blood glucose and blood pressure, and consult on medical problems. We identified 226 people (34.0%) in the shelters who might have had diabetes according to the consultation and/or blood glucose levels. Our team also established a telephone consulting service immediately after the earthquakes. We dealt with 31 consultations over the phone and three e-mails associated with glucose monitoring, antidiabetic agents, hypoglycemia and so on. The establishment of a DiaMAT and education of the team members in advance are definitely important for an early response to a disaster. In Table 3, >90% of the patients could not appropriately acquire medical information, which was unexpectedly high. There might be a limit to distributing information by a paper-based medium. First-line medical team-led information delivery and push type or bi-directional communicating applications on their smart phones should be considered.

Our investigation during the Kumamoto earthquake showed that glycemic control in patients with type 1 diabetes was stable; however, that in type 2 diabetes patients decreased by 0.11% at 1–2 months after the earthquake and increased thereafter.

The unaltered glycemic control in type 1 diabetes might be because 27.3% of patients changed their insulin doses based on self-judgment (20.0% reduced and 7.3% increased). They have communities through social networking services with whom

they can discuss insulin doses, food intakes, carbohydrate count and glucose monitoring. This might also have helped to maintain their glucose levels.

In patients with type 2 diabetes, glycemic control unexpectedly decreased at 1–2 months after the earthquakes. This reduction was negatively correlated with prompt recovery of lifelines and sufficient amount of sleep. These two components might contribute to emotional stability (anti-anxiety) in patients with type 2 diabetes to survive at that time. Indeed, distress, anxiety and/or stress cause glycemic deterioration in patients with diabetes¹². This deteriorative reaction can be explained by increased production of cortisol and/or catecholamine¹³. Insufficient or disturbed sleep and circadian misalignment might have a negative impact on glycemic control in patients with diabetes¹⁴.

After 3–4 months or longer, patients with type 2 diabetes showed worsened glycemic control. These deteriorations are positively correlated with the insufficiency of antidiabetic agents, insufficient food supply, largely destroyed houses and changes in working environment, which cannot be controlled by the patients themselves, but are directly associated with their mental and physical stress levels. This result also implies that the stress component during a severe disaster might be dependent on the time after it. Thus, glycemic control, associated factors and stress levels are altered in chronological order, and depend on the severity of the damage and changes in environment.

We propose that the immediate recovery of lifelines and ensuring a sufficient amount of sleep are important effectors to help control blood glucose levels in the early period after a disaster. In the medium term, making arrangements for antidiabetic agents and food supply have to be taken care of. In the long term, public administrations and/or workplaces should consider the situations of affected patients, and propose early counterplans for house reconstruction and/or keeping work environments stable to minimize their stress levels. These long-term impact factors cannot be managed by patients with diabetes or medical caregivers alone, and have to be tackled by society as a whole. Therefore, it is important to provide a message that we have to take comprehensive care of patients with diabetes affected by a disaster. Post-disaster diabetic medical care must consider these corresponding points in accordance with the time-period.

ACKNOWLEDGMENTS

The authors thank the staff from the Center for Clinical Research (Sonoko Ishihara, Megumi Tamura, Manami Sakurada, Megumi Sakamoto, Takako Tsuda) for their help with carrying out the research. We also thank Tokunori Ikeda, Jun Morinaga and Yoshinori Yamanouchi for helping to collect and assess the data. This research was supported by NPO Blue Circle 2050 (Cooperation No. 4330005009181).

DISCLOSURE

The authors declare no conflict of interest.

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