# Internet Diabetic Patient Management Using a Short Messaging Service Automatically Produced by a Knowledge Matrix System

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Lifelong strict self-care is essential in the management of diabetes, along with easy access to the health care system (1–3). However, there is an evident limitation in fulfilling these conditions in the current health care system, which is oriented toward outpatient care (4–7). Thus, various strategies have been designed to improve the quality and efficiency of treating diabetic patients.

Wireless technology is a worldwide communication system that allows a person to contact others anywhere at any time. Therefore, doctor-patient communication becomes possible anywhere with the use of this system (8). Currently, in civilized countries, nearly all adults and adolescences have their own cellular phones and use short message services (SMSs) in their daily lives. Moreover, numerous people are using ultra-fast Internet services at work or in the home. We designed an Internet-based diabetic patient management system using SMS that was automatically produced by a knowledge matrix. Subsequently, we compared biochemical profiles and clinical status between diabetic patients who used our system for 12 weeks and those who received the conventional outpatient management over the same time period.

**RESEARCH DESIGN AND METHODS** — We developed a knowledge matrix containing information on proper diet and exercise for diabetic patients based on the Korea Staged Diabetes Management Guideline (Table 1). Moreover, with the technical assistance from ISU UBCare, we created a Web site program (http://yds.healthkorea.net) that was used to formulate appropriate messages through an automated algorithm. We also designed a device that had the dual function of a glucometer and a pedometer. By connecting this device to the patient's cellular phone, the measured data on the device were automatically transmitted to his/her personal data sheet on the Web site. Patients were asked to keep a record on the Web site of how much and what kind of food they ate, as well as how much they exercised. When these data were sent to the main menu, our system automatically composed messages that were then sent to the patient. In addition, patients could check their clinical data by logging into the Web site where they could obtain various information on diabetes and incorporate the information into their daily lives for better self-management of diabetes.

Eighty type 2 diabetic patients were recruited (mean age 48.1 ± 9.6 years, duration of diabetes 7.8 ± 6.7 years, 65.0% male). They were randomly divided into intervention and control groups equally. Patients were excluded if they had any concomitant disease that might affect the outcomes of the study or patient compliance (9).

We measured anthropometric data, blood pressure, and biochemical profiles of the participants after 8 h of fasting at the start of the study and at 12 weeks. Patients in the intervention group were taught how to use our system for 12 weeks without any outpatient visits. Patients in the control group were provided with glucometers and received their usual outpatient management from their physicians. The protocol was approved by the local ethical committee.

**RESULTS** — Thirty-five patients in the intervention group and 36 patients in the control group completed the experimental protocol over a 12-week period. During the study period, the intervention group checked blood glucose more frequently than the control group (167.1 ± 88.2 vs. 44.6 ± 24.4, $P < 0.001$). The average frequency of diet-related data input and pedometer data transfer to the system in the intervention group was 12.7 ± 3.0 and 56.9 ± 13.7 per day, respectively. After 12 weeks, daily calorie consumption increased significantly in the intervention group (from 178.1 ± 76.4 to 381.3 ± 132.1 kcal, $P < 0.001$).

Neither drug modification nor a hypoglycemic event was reported in the two groups during the trial. Upon the follow-up examination at 12 weeks, the body weight was decreased from 66.6 ± 11.8 to 64.7 ± 10.2 kg in the intervention group ($P = 0.037$), while no change was observed in the control group (69.7 ± 12.1 to 69.2 ± 11.1 kg, $P = 0.117$). A significant reduction in A1C was observed in the intervention group (from 8.06 ± 1.40 to 7.34 ± 1.07%, $P < 0.001$) but not in the control group. Fasting and postprandial glucose levels were also significantly decreased in the intervention group (from 159.4 ± 43.7 to 132.3 ± 29.8 mg/dl, $P < 0.001$ and from 233.4 ±

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**Abbreviations:** SMS, short message service.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

**Table 1—*Organization of the knowledge matrix system***

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| Blood glucose (fasting, 2 h postprandial, and bedtime) |
| Assessment of daily blood glucose levels |
| Assessment of mean blood glucose levels over a week, frequency of blood monitoring and hypoglycemic and hyperglycemic events during a week, and comparison with the previous week |
| Assessment of mean blood glucose levels over a month, frequency of blood monitoring and hypoglycemic and hyperglycemic events during a month, and comparison with the previous month |
| Diet |
| Assessment of daily caloric intake and meal balance |
| Assessment of weekly caloric intake, meal balance, and high-fat diet and comparison with the previous week |
| Assessment of monthly caloric intake, meal balance, high-fat diet, and weight and comparison with the previous month |
| Exercise |
| Assessment of duration, frequency, and types of daily exercise |
| Assessment of duration, frequency, and types of weekly exercise and comparison with the previous week |
| Assessment of duration, frequency, and types of monthly exercise and comparison with the previous month |

The contents of the messages are composed of assessment ($n$ = 142), recommendation ($n$ = 52), encouragement ($n$ = 74), and compliment ($n$ = 56) that correspond to the patient's current status concerning their glucose level, diet, and exercise.

95.7 to 180.9 ± 59.4 mg/dl, respectively, $P$ = 0.001). However, no such changes were observed in the control group.

At the end of this study, A1C levels were significantly decreased in the intervention group compared with the control group (0.72 ± 0.80 vs. 0.15 ± 0.85% Δ from baseline, respectively, $P$ = 0.005). Fasting glucose and postprandial glucose levels were also significantly decreased in the intervention group compared with the control group (27.1 ± 38.6 vs. 2.3 ± 33.8 mg/dl Δ from baseline, $P$ = 0.005 and 52.5 ± 82.3 vs. 2.5 ± 65.1 mg/dl Δ from baseline, respectively, $P$ = 0.006). However, total cholesterol, triglyceride, and LDL and HDL cholesterol levels in the intervention group were not significantly different compared with those in the control group ($P$ = 0.194, 0.897, 0.951, and 0.105, respectively).

**CONCLUSIONS**— Web-based diabetes management systems that provide interactive components have already been proven to be effective in glucose control (10). However, our study was unique in that clinical recommendations were automatically generated through the preformed knowledge algorithm. There were several reasons for the improved glucose control in the intervention group. Primarily, the patients were provided with medical advice more often than those in the control group. Besides, they received medical feedback based on their most recent clinical data. These factors may have inspired the patients to more actively modify their lifestyle for better glucose control. In particular, the pedometer data that represented the amount of patient's daily activity might actually serve as a strong motivator for the patients to exercise more (11–13).

Of the 40 patients in the intervention group, 35 patients completed the study. Of five patients withdrawn from the study, three used our system throughout the study period, whereas two did not revisit our hospital at 12 weeks. Therefore, at the end of this study, patient compliance with our new system was 92.5% (37 of 40), and the survey on patient satisfaction scored 4.1 points out of 5 (data not shown). Our system not only lowered the patients' blood glucose levels but also helped sustain the decreased levels because the system could continuously prompt the patient's intrinsic motivation to control their glucose levels.

Furthermore, we believe our system, which provides patients with medical advice formulated from an automated algorithm via SMS, is far more economic than the similar systems previously introduced (8), in which medical personnel were required for the same process.

In this study, although we have demonstrated that our system can reduce A1C levels during a short-term study period of 12 weeks, the long-term effectiveness of the system on the management of diabetes remains to be determined.

In conclusion, our study suggests that Internet-based monitoring and computerized management of diabetes may be more effective than the conventional management. However, more studies are required before it can be universally used.

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