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Original Article

Effectiveness and Practicality of eKTANG as a Digital Treatment for Diabetes and Relevant Influence Factors

Xiaohua Lu [1], Dalong Guo [2], Lie Feng [1], Yan Zhou [3], Chuangbiao Zhang [1], *Jiaying Li [1], Yin Jiang [2]

1. *Department of Endocrinology, First Affiliated Hospital of Jinan University, Guangzhou, China*
2. *Zhejiang Idoctor Health Technology Company Limited, Hangzhou, China*
3. *Department of Interventional Orthopaedics, First Affiliated Hospital of Jinan University, Guangzhou, China*

***Corresponding Author:** Email: j5fpvc@163.com

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Abstract

Background: This work explored the effect of eKTANG, a new healthcare mode for diabetes patients, on diabetes management.

Methods: Allowing general utilization of medical service and health management based on Internet, eKTANG obtained the precise data like blood glucose and blood pressure examined by an intelligent glucometer, from which doctors and the nursing team will promptly analyze the data and return feedback to the patients. In our study, overall 204 patients receiving eKTANG management over 3 months in First Affiliated Hospital of Jinan University from May 2019 to Aug 2020 were enrolled as the research objects, with data collected from patient records.

Results: Through the biochemical test on relevant indexes of blood glucose, it was observed that FBG, PBG, HbA1c, TG, TC, LDL levels after management were lower than before whereas HDL expression after were lower than before. Contrasted with substandard group, standard group performed younger age, lower proportion of the married, decreased proportion of microvascular and macrovascular complications, longer course of disease, more frequent glucose monitoring, declined time of hyperglycemia and time of alarms, elevated time of euglycemia, increased proportion of diet control, more amount of exercise and higher compliance, as the number of patients choosing oral medicine in standard group was more than substandard group. The course of disease and time of hyperglycemia were risk factors of HbA1c standard reaching whereas frequency of glucose monitoring (≥1 time/week) and time of euglycemia were protective factors.

Conclusion: eKTANG effectively improved diabetes management.

Keywords: Diabetes; Effectiveness and precision; Internet remote platform

Introduction

Diabetes is a metabolic disorder characterized by an aberrant long-term rise of blood glucose level (1). In 2017, there were about 4,000,000 people dying from diabetes, accounting for 10.7% of all-cause deaths globally (2). Furthermore, the incidence of diabetes continuously increases and the

number of adult diabetes patients worldwide is predicted to reach nearly 700,000,000 by 2045 (3-5). As the largest diabetes country with 25% of diabetes patients around the world living in China, the similar trend is also found in China and goes even farther (6). With the long-term treatment, high morbidity and various complications, diabetes results in not only the negative physical and mental influence but also the huge economic (7-11). Hyperglycemia, a main sign for diabetes and a major cause of diverse complications in diabetes, is correlative to a poor prognosis of diabetes patients (12). Hence, blood glucose control is pivotal for ameliorating outcome of diabetes patients.

In developed countries, diabetes treatment and control are patient-centered, focusing more on patient self-management and lifestyle modification rather than drug therapy and physician intervention (3, 13). Nevertheless, in developing countries, the diabetes is not interfered until the initiation of the disease or even diabetes complications, with the treatment based mostly on the medication (3, 14, 15). In China, although more attention has been paid into that patient-centered approach for diabetes treatment and control and a certain effect has been achieved in several studies (3, 16-19), diabetes self-management still remains in its infancy.

The eKTANG is a new healthcare mode for diabetes patients. Combining Internet technology with healthcare, eKTANG allows general utilization of medical service and health management based on Internet. Through an intelligent glucometer, the precise data like blood glucose and blood pressure are transmitted to eKTANG background, from which doctors and the nursing team will promptly analyze the data and return feedback to the patients. The application (APP) enables remote patients to realize diabetes treatment and control via self-management in multiple aspects (exercise, diet, etc.) under the professional guidance of the medical team.

We aimed to evaluate the implementation effect of eKTANG on diabetes patients.

Materials and Methods

Subjects and data

Cases of diabetes receiving eKTANG management over three months in First Affiliated Hospital of Jinan University from May 2019 to Aug 2020 were enrolled as the research objects. This study was approved by the Ethics Committee of First Affiliated Hospital of Jinan University (FA20190505608), with informed consent signed. Clinical data in the research were collected from patient records. Overall, 210 patients were incorporated into the research, among whom 6 patients were excluded due to lack of clinical data. Eventually, data pertaining to 204 patients were included in the analysis.

Implementation plan

Doctors instructed their own patients in downloading eKTANG APP equipped with a customized intelligent glucometer, with primary nurses responsible for teaching patients relevant information. After discharge from the hospital, patients were required to record each index through the APP, based on which doctors formulated a corresponding scheme that was then transmitted to the nursing team for managing patients. For blood glucose emergency/abnormality (blood glucose $\leq$ 3.9 mmol/L or $\geq$ 16.9 mmol/L), the alarm would be sounded for a timely intervention.

Outcome measures

The application effect of the eKTANG was assessed mainly according to the changes in the following indicators from May 2019 to Aug 2020: self-management behavior, relevant indexes before and after management and analysis of blood glucose standard and hypoglycemia.

Self-management behavior

The data of self-management behaviors were collected through follow-up by telephone, outpatient service and APP background, including frequency of glucose monitoring, time of glucose monitoring, time of hypoglycemia (patients

whose blood glucose is lower than the minimum target set by doctors), time of hyperglycemia (patients whose blood glucose is lower than the maximum target set by doctors), time of euglycemia, time of alarms (blood glucose ≤ 3.9 mmol/L or ≥ 16.9 mmol/L), diet control, exercise, compliance, use of hypoglycemic agents, frequency of return visit and management (patients taking eKTANG management by self or caregiver).

Relevant indexes before and after management

FBG, PBG, HbA1c, SBP, DBP, BMI, TG, TC, LDL, HDL, ALT and Cr were all biochemical indexes associated with blood glucose, which were measured by the customized intelligent glucometer and later automatically uploaded to the background of APP for data collection.

Analysis of blood glucose standard and hypoglycemia

Blood glucose standard-reaching rate, level of blood glucose standard-reaching rate, time of hypoglycemia and hypoglycemia level were analyzed in this part, with the relevant data obtained from background of APP through measurement by glucometer. Blood glucose standard-reaching rate was calculated as the number of diabetes with HbA1C < 7% divided by the total number of diabetes patients. The "hypoglycemia" in time of hypoglycemia and hypoglycemia level referred to the blood glucose ≤ 3.9 mmol/L.

Statistical analysis

Statistical analysis was made by SPSS 20.0 software (SPSS, Chicago, IL, USA). Measurement data was performed as the means ± standard deviation, as the relevant indexes before and after management contrasted by Student's *t* test. Enumeration data were presented as case number. Univariate analysis was evaluated through chi-squared test, whereas multivariable analysis was done using binary logistic regression analysis. $P < 0.05$ implicated a statistically significance.

Results

Patient characteristics

Table 1 shows the clinical data (follow-up time, age, gender, marital status, education background, residence, monthly income, Internet time, course of disease, family history of diabetes, smoking history, drinking history, microvascular complication and macrovascular complication) of patients.

Table 1: Clinical data of the patients

Variables	*Mean value/N (n=204)*	*Proportion (%)*
Follow-up time (Days)	211.7±129.0	
Age (yr)	52.6±14.4	
Gender		
Male	118	57.8
Female	86	42.2
Marital status		
Married	189	92.6
Divorced/widowed	2	1.0
Single	13	6.4
Education background		
Primary school or below	43	21.1
Junior high school	37	18.1
High school or technical secondary school	52	25.5
Junior college or above	72	35.5
Residence		
Urban	174	85.3
Suburb	30	14.7

Monthly income		
<3000	53	26.0
3000~5000	26	12.7
＞5000	125	61.3
Internet time	6.3±4.0	
Course of disease (years)	4.9±5.8	
Family history of diabetes		
Yes	68	33.3
No	136	66.7
Smoking history		
Yes	37	16.7
No	167	81.9
Drinking history		
Yes	35	17.2
No	169	82.8
Microvascular complication		
Yes	107	52.5
No	97	47.5
Macrovascular complication		
Yes	73	35.8
No	131	64.2

Self-management behaviors

Table 2 presents self-management behaviors comprising frequency of glucose monitoring, time of glucose monitoring, time of hypoglycemia, time of hyperglycemia, time of euglycemia, time of alarms, diet control, exercise, compliance, use of hypoglycemic agents, frequency of return visit and management.

Table 2: Self-management behavior of patients

Variables	*Mean value/N (n=204)*	*Proportion (%)*
Frequency of glucose monitoring (times/month)		
No monitoring	17	8.3
<1 time/month	10	4.9
≥1 time/month	35	17.2
≥1 time/week	142	69.6
Time of glucose monitoring	251.7±219.9	
Time of hypoglycemia	6.8±14.5	
Time of hyperglycemia	61.4±78.7	
Time of euglycemia	183.5±173.5	
Time of alarms	8.3±20.3	
Diet control		
Yes	188	92.2
No	16	7.8
Exercise		
No exercise	24	11.8
≤150 min/week	56	27.5
≥150min/ week	124	60.8
Compliance		

Yes	181	88.7
No	11	5.4
Did not take medicine	12	5.9
Use of hypoglycemic agents		
Oral medicine	119	58.3
Insulin	16	7.8
Oral medicine+insulin	57	27.9
Life intervention	12	5.9
Frequency of return visit		
No visit	6	2.9
Every 2-3 months	110	53.9
Monthly	17	8.3
> 3 months	71	34.8
Management		
Self	142	69.6
Caregiver	62	30.4

EKTANG management improved relevant indexes of diabetes patients

As shown in Table 3, the levels of FBG, PBG, HbA1c, TG, TC, LDL after management were prominently lower than those before management whereas HDL expression after management obviously declined in comparison with that before management.

Table 3: Comparison of relevant indexes before and after management

Indexes	*Before management*	*After management*	*t*	*P*
FBG (mmol/L)	8.4±3.7	7.0±2.2	5.296	0.000
PBG (mmol/L)	11.3±5.5	8.7±3.2	6.614	0.000
HbA1c (%)	9.8±3.1	6.8±1.4	12.524	0.000
SBP (mmHg)	128.3±15.1	126.2±14.5	2.371	0.019
DBP(mmHg)	75.5±13.4	75.6±12.8	-0.104	0.917
BMI (kg/m^2)	24.5±4.1	24.1±4.0	2.974	0.003
TG (mmol/L)	2.3±2.9	1.6±1.4	3.888	0.000
TC (mmol/L)	4.9±1.3	4.4±1.1	5.673	0.000
LDL (mmol/L)	2.8±0.9	2.5±0.9	5.361	0.000
HDL (mmol/L)	1.1±0.3	1.2±0.4	-3.166	0.002
ALT (U/L)	34.0±39.1	26.4±16.0	2.800	0.006
Cr (μmol/L)	73.5±60.6	74.5±36.4	-0.298	0.766

Analysis of blood glucose standard and hypoglycemia in patients

Table 4 exhibits patients' conditions of blood glucose standard and hypoglycemia, which consists of blood glucose standard-reaching rate, level of blood glucose standard-reaching rate, time of hypoglycemia and hypoglycemia level.

Table 4: Analysis of blood glucose standard and hypoglycemia in patients

Variables	*Mean value/N (n=204)*	*Proportion (%)*
Blood glucose standard-reaching rate (%)	71.5±21.3	
Level of blood glucose standard-reaching rate		
＜60%	56	27.5
60-80%	65	31.9
＞80%	83	40.7
Time of hypoglycemia	3.3±6.9	
Hypoglycemia level		
Unhappen	81	39.7
≤3.9 mmol/L	49	24.0
≤3.0 mmol/L	74	36.3

The factors related to HbA1c standard reaching

The univariate analysis presented that there was no marked difference in gender, education background, residence, monthly income, internet time, family history of diabetes, smoking history, drinking history, time of glucose monitoring, time of hypoglycemia, frequency of return visit, management and hypoglycemia level between standard group and substandard group. Compared with substandard group, patients of standard group performed the younger age as well as the lower proportion of the married. In addition, the course of disease in standard group was longer than substandard group. In addition, decreased proportion of microvascular and macrovascular complications were observed in standard group when compared with substandard group. Moreover, glucose monitoring of patients in standard group was more frequent than substandard group, as time of hyperglycemia and time of alarms in standard group dramatically lower than substandard group while time of euglycemia in standard group was higher than substandard group. Besides, patients of standard group possessed elevated proportion of diet control, more exercise as well as higher compliance in comparison with substandard group. Using hypoglycemic agents was also a factor with significant difference between standard group and substandard group, as the number of patients choosing oral medicine in standard group was more than substandard group (Tables 5-7).

Table 5: Univariate analysis

Variables	*Standard(n=136)*		*Substandard (n=68)*		*P*
	Mean value/N	%	Mean value/N	%	
Age (yr)	50.1±15.1		57.6±11.4		0.000
Gender (male)	79	58.1	39	57.4	0.920
Marital status					0.082
Married	123	90.4	66	97.1	
Divorced/widowed	1	0.7	1	1.5	
Single	12	8.8	1	1.5	
Education background					0.124
Primary school or below	25	18.4	18	26.5	
Junior high school	24	17.6	13	19.1	
High school or technical secondary school	35	25.7	17	25.0	
Junior college or above	52	38.2	20	29.4	

Residence					0.675
Urban	115	84.6	59	86.8	
Suburb	21	15.4	9	13.2	
Monthly income					0.102
<3000	30	22.1	23	33.8	
3000~5000	18	13.2	8	11.8	
＞5000	88	64.7	37	54.4	
Internet time	6.2±4.0		6.6±4.3		0.496
Course of disease (years)	8.1±6.3		3.3±4.8		0.000

Table 6: Univariate analysis

Variables	***Standard(n=136)***		***Substandard (n=68)***		***P***
	Mean value/N	%	Mean value/N	%	
Family history of diabetes					0.674
Yes	44	32.4	24	35.3	
No	92	67.6	44	64.7	
Smoking history(Yes)	22	16.2	14	20.6	0.436
Drinking history(Yes)	22	16.2	12	17.6	0.790
Microvascular complication					0.002
Yes	61	44.9	46	67.6	
No	75	55.1	22	32.4	
Macrovascular complication					0.039
Yes	42	30.9	31	45.6	
No	94	69.1	37	54.4	
Frequency of glucose monitoring (times/month)					0.000
No monitoring	6	4.4	11	16.2	
<1 time/month	6	4.4	4	5.9	
≥1 time/month	16	11.8	19	27.9	
≥1 time/week	108	79.4	34	50.0	
Time of glucose monitoring	230.2±189.9		262.4±233.4		0.325
Time of hypoglycemia	6.8±12.4		6.8±15.4		0.989
Time of hyperglycemia	44.2±61.9		95.8±96.1		0.000

Through multiple regression analysis, we discovered that course of disease, frequency of glucose monitoring (≥1 time/week), time of hyperglycemia as well as time of euglycemia could affect HbA1c standard reaching in the different way, as the course of disease and time of hyperglycemia were risk factors of HbA1c standard reaching whereas frequency of glucose monitoring (≥1 time/week) and time of euglycemia were protective factors HbA1c standard reaching (Table 8).

Table 7: Univariate analysis

Variables	*Standard(n=136)*		*Substandard (n=68)*		*P*
	Mean value/N	%	Mean value/N	%	
Time of euglycemia	211.4±191.2		127.6±112.8		0.000
Time of alarms	5.4±16.7		14.1±25.1		0.010
Diet control					0.000
Yes	134	98.5	54	79.4	
No	2	1.5	14	20.6	
Exercise					0.001
No exercise	11	8.1	13	19.1	
≤150 min/week	30	22.1	26	38.2	
≥150min/ week	95	69.9	29	42.6	
Compliance					0.001
Yes	121	89.0	60	88.2	
No	3	2.2	8	11.8	
Did not take medicine	12	8.8	0	0.0	
Use of hypoglycemic agents					0.003
Oral medicine	83	61.0	36	52.9	
Insulin	10	7.4	6	8.8	
Oral medicine+insulin	31	22.8	26	38.2	
Life intervention	12	8.8	0	0.0	
Frequency of return visit					0.104
No visit	3	2.2	3	4.4	
Every 2-3 months	81	59.6	29	42.6	
Monthly	11	8.1	6	8.8	
> 3 months	41	30.1	30	44.1	
Management					0.590
Self	93	68.4	49	72.1	
Caregiver	43	31.6	19	27.9	
Hypoglycemia level					0.239
Unhappen	54	39.7	27	39.7	
≤3.9 mmol/L	37	27.2	12	17.6	
≤3.0 mmol/L	45	33.1	29	42.6	

Table 8: Multiple regression analysis

Variables	*OR*	*95% CI*	*P*
Age (yr)	1.015	0.975-1.057	0.458
Marital status			
Married			
Divorced/widowed	11.271	0.545-233.191	0.117
Single	0.524	0.031-8.821	0.654
Course of disease (years)	1.129	1.040-1.226	0.004
Microvascular complication			
Yes			
No	0.461	0.178-1.194	0.111
Macrovascular complication			
Yes			
No	1.212	0.477-3.079	0.686
Frequency of glucose monitoring			

(times/month)			
No monitoring			
<1 time/month	0.442	0.061-3.184	0.418
≥1 time/month	0.852	0.182-3.984	0.839
≥1 time/week	0.177	0.044-0.710	0.015
Time of hyperglycemia	1.018	1.008-1.028	0.000
Time of euglycemia	0.991	0.985-0.996	0.001
Time of alarms	0.993	0.960-1.027	0.687
Diet control			
Yes			
No	4.340	0.681-27.663	0.120
Exercise			
No exercise			
≤150 min/week	1.083	0.280-4.189	0.908
≥150min/ week	1.147	0.298-4.416	0.842
Compliance			
Yes			
No	3.564	0.589-21.546	0.166
Use of hypoglycemic agents			
Oral medicine			
Insulin	2.096	0.331-13.286	0.432
Oral medicine+insulin	0.410	0.144-1.169	0.095

Discussion

According to a former reporter, a collaborative daily self-management scheme is better for non-communicable disease (3). As a creative pattern integrating information technology and medical care, the remote management system for diverse diseases containing diabetes, which is believed to be a promising tool realizing the collaborative daily self-management, have already been studied in developed countries, with the efficiency and practicality validated by many clinical trials (3, 13, 19). However, few such researches have been operated in China.

The awareness and treatment rates of diabetes patients have significantly elevated in China those years, indicating a rising health consciousness of diabetes patients. Nevertheless, diabetes control is still poor (20). The reasons may be as follows: lacking tracking analysis of complete daily blood glucose data (especially discharged patients), doctors can only formulate medication regimen based on clinical experience, which impedes timely and accurate management for diabetes.

CDSS-based u-healthcare service and the Internet-based blood glucose monitoring system both realized the better control for diabetes patients (21-23). Livongo for Diabetes Program is widely accepted as a successful example of diabetes management (24-27). EKTANG is an emerging Internet-based healthcare APP in China specially designed for diabetes patients. Generally, eKTANG has a similar mode to that of Livongo, through which data can be determined and delivered to a management team that will analyze the data and return in-time feedback to diabetes patients with medical support available. Furthermore, the alarm will sound when the specific events are monitored to remind patients and management team of timely and efficient intervention. The information shows that eKTANG pattern is in accord with the "five carriage" (medical treatment, kinesitherapy, dietotherapy, blood glucose monitoring, education of chronic disease) of diabetes management in China, suggesting the potential of eKTANG as a digital treatment in line with Chinese actual situations. Besides, consistent with researches above, our study observed that the blood glucose of diabetes patients were

improved after eKTANG management and it even achieved a greater effect with a more obvious decrease of HbA1c, implying the efficiency and superiority of eKTANG for diabetes control. A research about the role of 3Bs in diabetes patients reported that traditional management for diabetes in China mainly focuses on blood glucose control while ignores the crucial functions of blood pressure and lipid on diabetes treatment, which reveals the significance of 3Bs control during diabetes management (28). Agreeing with former other studies about the remote coaching system, Telemedicine and UCDC system (19, 29-31), eKTANG management not only improved blood glucose, but also ameliorated blood pressure and blood lipid in diabetes patients. Moreover, contrasted with the work about 3B approach for diabetes patients (28), eKTANG management fulfilled a better function on blood glucose control with a higher blood glucose standard-reaching rate, again supporting the positive effectiveness, practicality and superiority of eKTANG on managing and controlling diabetes. What's more, during eKTANG management, patients reaching standard HbA1c level performed younger age, lower proportion of the married, decreased proportion of microvascular and macrovascular complications, longer course of disease, more frequent glucose monitoring, declined time of hyperglycemia and time of alarms, elevated time of euglycemia, increased proportion of diet control, more amount of exercise, higher compliance and a higher proportion of oral medicine taken, as the course of disease and time of hyperglycemia were risk factors of HbA1c standard reaching whereas frequency of glucose monitoring and time of euglycemia (≥1 time/week) were protective factors of HbA1c standard reaching, which further explained the mechanism of eKTANG management and provided some insights into eKTANG optimization.

Conclusion

The work confirmed the effectiveness and practicality of eKTANG on diabetes management, providing a promising treatment method for diabetes patients in China.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interest.

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