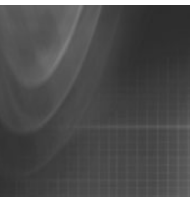
Longitudinal Effects of an Intergenerational mHealth Program for Older Type 2 Diabetes Patients in Rural Taiwan



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Purpose

The purpose of the study is to test the longitudinal efficacy of a mHealth intervention (Intergenerational Mobile Technology Opportunities Program, IMTOP) for older type 2 diabetes mellitus (T2DM) patients in rural Taiwan. Few mHealth programs targeted rural older adults and the longitudinal effects are unknown.

Methods

Ninety-seven T2DM patients aged 55+ were recruited from an outpatient in Hualien, Taiwan. The intervention comprised 8-week technology and diabetes self-management

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training and 4-week technical support. College student tutors facilitated T2DM patients to learn technology. Participants used a diabetes self-management app to track health behaviors. Outcomes measured at baseline and at 4 and 8 months including patient-reported self-care behaviors, T2DM symptoms, clinical outcomes, health resource utilization, and medical expenditure. Linear mixed-effect regressions of repeated measures were conducted for each outcome.

Results

At 4 months, improvements in self-care behaviors were reported in diet, exercise, smoking, and blood glucose testing. Patients paid less endocrinology clinic visits, spent less on endocrinology medications, and improvements in fasting blood glucose and total cholesterol were observed. At 8 months, the statistical significance of improvements in diet and smoking were maintained, and the averaged endocrinology clinic visits remained less than baseline. However, more frequent occurrence of diabetes symptoms were reported at both follow-ups.

Conclusions:

IMTOP had lasting effects on diet and decreased smoking behavior, clinic visits, and medication costs over 8 months. Self-monitoring through an app increased awareness and may explain the increased reporting of diabetes symptoms. IMTOP is a promising model for promoting T2DM self-management in rural areas.

Introduction

About 422 million adults were living with diabetes around the world in 2014, with 90% diagnosed with type 2 diabetes mellitus (T2DM).[1] The global health system and economies have been affected significantly by the cost of diabetes and its complications.[1] In Taiwan, 3 in every 10 people aged 65 years and above have T2DM.[2] With the rapidly aging population, T2DM management has become an increasingly evident challenge, especially in rural areas.

T2DM care disparities exist between urban and rural areas because of many barriers to health care in nonurban communities, such as distance and transportation, workforce shortage, and poor health literacy.[3] While 56% of global rural people are in deficit of health coverage, the rate is only 22% among the urban population.[4] In global rural regions, at least 7 million more health workers are needed to provide sufficient health care.[4] The increase in health care costs and health provider workload as a result of the high T2DM prevalence rate calls for an effective T2DM management program in rural settings.[5]

Mobile technology has the potential to address the challenge of T2DM care in rural areas by providing new avenues to access health knowledge[6,7] and promoting self-care through reminding and health behavior tracking.[8] Mobile health technologies (mHealth) extend care beyond health care organizations, which has been used as an intervention tool to enhance T2DM self-management.[5,9-11] Despite the increased ownership and use of mobile devices,[12] mHealth tools are underused among rural older T2DM patients.[13,14] Systematic reviews highlight the lack of mHealth research in rural patients with T2DM as an important knowledge gap and practice opportunity.[15] While telehealth interventions have been tested and implemented in rural areas, no previous studies have examined the potential of mhealth to address the T2D care disparities in rural regions.

A mHealth intervention is more likely to bring positive results when delivered with social support.[11,15] Older adults face a unique set of barriers that can prevent them from using mobile health tools, such as limited previous experience with technology, lack of motivation to learn and used technology, and physical health challenges.[13] On the other hand, young people are fluent users of mobile technology and the so-called "digital natives".[13] To the authors' knowledge, no previous mHealth intervention study for older T2DM patients has included an intergenerational support component, although it could potentially be beneficial for both generations.[5,9,11,15-17] The intergroup contact theory posits that frequent interactions between older and younger generations create social capital for both groups.[18] Resorting to young people for teaching and motivating older patients with T2DM to use mHealth tools may help in overcoming the aforementioned barriers for technology adoption. Meanwhile, younger people can learn T2DM knowledge and increase their health awareness at an early age, thus preventing the occurrence of chronic disease in the long run.[19]

This study examined the efficacy of a mHealth intervention program integrated with a unique intergenerational support design for the underinvestigated, high-need rural population. The Intergenerational Mobile Technology

Opportunities Program (IMTOP) is a mHealth intervention that recruited college-student tutors to help older patients to learn how to use mobile technology and a health tracking app for diabetes self-management. This article aims to answer the research question: What are the clinical and practical impact of IMTOP? The longitudinal change in four categories of patient outcomes were examined, namely, self-management behaviors, diabetes symptoms, clinical outcomes, and health care resource utilization. The researchers hypothesized that compared to the control group, the participants of the IMTOP intervention would show increased frequency of self-management behaviors, improved clinical outcomes, and reduced health resource utilization and medical expenditure post the intervention and at follow-up assessments.

Methods

Study Design

IMTOP was conducted in collaboration with the Tzu Chi hospital in Hualien, Taiwan. Only 7% of the land in Hualien county is inhabited by people,[14] and its total population at the end of 2016 ranked 20 out of 22 counties in Taiwan.[14,20] This study was reviewed and approved by the University of Southern California Internal Review Board (IRB) and the Tzu Chi hospital's Research Ethics Committee before data collection, and registered in clinicaltrials.gov (ID: NCT02971241).

This article examined the intervention effect over an 8-month period. Patients with T2DM attended an 8-week group training program and were followed up for up to 8 months (calculated from the start of the intervention). Evaluating questionnaires were administrated in person or by telephone at baseline and at 4 and 8 months after the intervention started. Medical records and laboratory test results since 1 year before enrollment until the end of IMTOP observation period were obtained from the hospital.

Participants

Individuals were eligible to participate if they were current hospital patients, aged ≥55 years, had a diagnosis of T2DM for at least 6 months, understood Mandarin and had the ability to read a Chinese newspaper, had normal eye-hand coordination, were able to regularly attend the IMTOP training course, and had a working telephone or mobile phone. Exclusion criteria included having a score of ≥2 on the CAGE alcohol questionnaire[21]; schizophrenia, affective disorder, manic depression, or lithium requirement; and a cognitive impairment precluding the ability to provide informed consent, that is, a Short Portable Mental Status Questionnaire score of ≥4.[22,23] Patients were recruited from February to April 2016.

Intervention Description

The IMTOP intervention comprised 8 small-group training weekly sessions (10-12 people per class) followed by a 4-week technical support period. Training themes included tablet use skills, an introduction to the Internet and the online community, use of mobile applications to fulfill daily and health care needs, peer and professional support for diabetes care, and diabetes self-management knowledge and skills. In each class, a lecture was delivered by a trained IMTOP research staff member. College student tutors, who were trained by attending online courses, conducted simultaneous digital technology skill sessions and provided individualized support to participants. College student tutors either volunteered to or received college service learning credits as a result. The 4-week technical support was provided by research staff members as an additional help.

During and continually after the intervention period, participants were invited to use on their tablets a diabetes self-management app (IMTOP app) previously developed by the research team, in which they could record their diet, physical activity, foot check, water consumption, medication adherence, blood glucose, blood pressure, weight, and mood. Recorded data were transmitted via Internet to the web-based database. Data collection occurred from April to December 2016.

Data Collection and Measurements

Baseline interviews were conducted in person or over the telephone, according to participants' preference. Four- and 8-month follow-up surveys were conducted via telephone by part-time interviewers. Intervention outcomes were measured for T2DM symptoms and complications, self-care behaviors, and clinical outcomes at the following 3 time points.

T2DM Symptoms and Complications

Diabetes symptoms were assessed using the Self-Completion Patient Outcome Instrument (SCPOI).[24] With SCPOI, participants used the 5-point Likert scale (1 =

never, 5 = every day) to rate the frequency at which they observed the following 9 diabetes symptoms: abnormal thirst, blurred vision, excessive water press, unusual hunger, feeling shaky, cold hands and feet, feeling sleepy, feelings of pins and needles, and passing out. A symptom was classified as a "positive symptom" when the participant reported its occurrence "on several days" (Likert scale ≥3). The number of positive symptoms was calculated (possible range: 0-9), and their frequency was associated with a level of severity by summing individual item scores and linearly transforming them into a range of 0 to 100, where 100 represented the poorest possible status.

Participants also indicated if they had 1 or more of the following types of diabetic complications: vision problems; loss or decreased feeling in feet or legs; kidney problems; unclear foot pain, infection, or amputation; sexual impairment; heart attack; or a cardiac procedure to clear blocked vessels. The scale score consisted of the sum of complications, ranging from 0 to 7.

Self-Care Behaviors

Participants reported the number of days in a week that they conducted diabetes self-care behaviors (eg, specific diet, exercise, and blood glucose testing) using the Summary of Diabetes Self-Care Activities (SDSCA).[25] The Chinese version of SDSCA has been validated in Hong Kong patients.[25] SDSCA includes 2 items measuring general diet (follow a healthy eating plan in last 7 days and monthly averaged days per week), 2 items on diabetes-specific diet (consume fruits and vegetables, reverse-coded item on eating high-fat products), 2 items on exercise (physical activity, exercise), 2 items on self-monitoring of blood glucose (test blood glucose, test blood glucose at frequency advised by doctors), 2 items on foot care (check feet and inspect shoes), and 1 item on smoking.[25] The Cronbach's alpha values for these parameters were .98, .81, .65, .88, and .62, respectively.[25] SDSCA showed satisfactory validity (goodness-of-fit index = .77).[25]

Clinical Outcomes

General and endocrinology clinic visits, cost of prescription medications, and laboratory test results from 1 year before enrollment until the end of the IMTOP study were retrieved from the hospital's electronic medical records. Medical care visits and medication costs were aggregated and summed for each specific time frame, in uniform 4-month periods. Medical costs were converted to US dollars (USD) with a 30:1 conversion rate. If a specific laboratory test was performed multiple times within a given time frame, the most recent test result was used. If no test was performed in a specific time frame, the most recent available result was carried forward.

In addition to the aforementioned outcome variables, researchers collected demographic information at baseline, including age, sex, education (elementary, junior high, high school, college and above), marital status (1 = married, 0 = others), living arrangements (1 = live alone, 0 = others), and employment (1 = employed, 0 = not employed).

Statistical Analysis

All statistical analyses were performed using SAS for Windows version 9.3 (SAS Institute Inc, Cary, North Carolina). The program effects were evaluated using 3-wave repeated measures collected at baseline and at 2 follow-up points (one at 4 months and another at 8 months after the start of the intervention). To assess the program's longitudinal effects, repeated measures were analyzed for each dependent variable. Linear mixed-effect regression models were fitted for continuous outcome variables. The mixed-effect model operates on incomplete (ie, missing data) matrices and uses all available data with maximum-likelihood estimation. The specified mixed-effect model included a random intercept for each patient in an unstructured covariance structure to account for within-patient correlations of repeated observations; the model also examined the linear trend of changes over time. The contrasted mean scores estimated at each time point with baseline values are presented. The statistical tests were conducted at the 2-tailed significance level of .05.

Results

Recruitment Results

A total of 126 individuals with T2DM previously referred by their physicians were screened. All 126 patients met the inclusion criteria and were enrolled to participate. Of these participants, 12 refused or were unable to attend the class, and 17 refused to perform the baseline assessment. Of the 97 participants who attended IMTOP training, 1 refused to perform the 4-month follow-up and another, the 8-month follow-up. All 97 participants were included in the final analysis.

Sample Characteristics

Table 1 details the characteristics of the study sample. The mean age of the participants was 65.29 years (SD = 7.08), and 50.5% were men. Approximately 70% of participants were married, and 15.5% were employed. Half of the participants were educated below high school level. Most participants had comorbidities: About 50% presented with hypertension and 12.4% with heart disease. At baseline, 66% of participants had never used the Internet.

Intervention Effectiveness Results Over 8 months

Table 2 shows self-care behavior and diabetes symptoms changes at 4- and 8-month assessments. Improvements in self-care behaviors were observed (Table 2 and Figure 1) at the 4-month assessment for a specific diet (2.21 days/week increase, 95% CI, 1.78-2.64, $P < .0001$), exercise (0.68 days/week increase, 95% CI, 0.14-1.22, $P < .05$), smoking habits (0.44 days/week reduction, 95% CI, −0.76 to −0.13, $P < .01$), and blood glucose testing (1.26 days/week increase, 95% CI, 0.75-1.76, $P < .0001$). The magnitude of improvement in specific diet (2.39 days/week increase, 95% CI, 1.96-2.82, $P < .0001$) and smoking habits (0.43 day/week reduction, 95% CI, −0.74 to −0.11, $P < .01$) were maintained during the 8-month follow-up phase. Improvements in exercise, general diet, and blood glucose testing were not maintained at the 8-month follow-up. No intervention effect was observed for foot care, which remained at baseline levels throughout the entire study period.

Contrary to the hypothesis, an increased number of positive diabetes symptoms was reported at 4- and 8-month assessments compared with the baseline assessment. Participants reported 0.29 more positive symptoms at the 4-month time point (95% CI, 0.01-0.57, $P < .05$) and an additional 0.88 positive symptoms at 8 months (95% CI, 0.60-1.16, $P < .0001$). The self-reported frequency of diabetes symptoms also increased. On a scale from 0 to 100, participants reported a 2.58-point increase in the frequency of T2DM symptoms at 4 months (95% CI, 0.35-4.81, $P < .05$) and a 6.98-point increase at 8 months (95% CI, 4.75-9.21, $P < .0001$). Both change trends were significant ($P < .0001$).

The program's longitudinal impacts on medical service use and laboratory test outcomes are presented in Table 3. Figure 2 visualized key findings with significant changes during the 8-month period. Over 8-month study period, participants had fewer endocrinology visits compared to baseline (–0.4 visits on average at 4 months, $P < .0001$; –0.24 visits on average at 8 months, $P = .003$; linear trend test $P < .0001$) and spent less in medication (–21.69 USD on average at 4 months, $P = .001$; –11.43 USD on average at 8 months, $P = .075$; linear trend test $P = .004$). At 4 months, participants showed improvements in fasting blood glucose (12.33 mg/dL decrease, 95% CI, −22.54 to −2.12, $P = .018$) and total cholesterol (5.58 mg/dL decrease, 95% CI, −11.01 to −0.16, $P = .044$). Although the decrease in low-density lipoprotein (LDL) was not statistically significant at 4 months (averaged decrease 3.72 mg/dL, $P = .115$), the magnitude of

Table 1

Study Sample Characteristics (N = 97)

	No.	%
Male	49	50.5
Age, mean (SD)	65.29	7.08
Marital status – married	68	70.1
Live alone	10	10.3
Employed	15	15.5
Education		
• Elementary	27	27.8
• Junior high (7th-9th grade)	23	23.7
• High school (10th-12th grade)	33	34.0
• College and above	14	14.4
Comorbid illness		
Hypertension	52	53.6
Heart disease	12	12.4
Urinary tract or prostate disease	6	6.2
Gastrointestinal disease	3	3.1
Eye disease (retinopathy)	3	3.1
Arthritis	3	3.1
Kidney disease	3	3.1
Cancer	2	2.1
Stroke (neurological disease)	2	2.1
Any comorbid disease listed above	60	61.9
Experience with technology		
Never use Internet (visit websites or send/receive email)	64	66.0

Table 2

Diabetes Symptoms and Self-Care Behaviors Change From Baseline to 4-Month and 8-Month Follow-Ups

Characteristic	Time*	Least Squares Mean (SE)	Change Score (Δ Since Baseline) Mean	95% CI	*P* Value
Diabetes self-care (No. of days per week)					
General diet	Baseline	5.15 (0.20)			
	4 months	5.57 (0.20)	0.42	–0.11 to 0.95	.123
	8 months	4.62 (0.20)	–0.52	–1.06 to 0.01	.055
	Trend *P* value[a]	.003			
Specific diet	Baseline	1.50 (0.15)			
	4 months	3.71 (0.15)	2.21	1.78, 2.64	<.0001
	8 months	3.88 (0.15)	2.39	1.96, 2.82	<.0001
	Trend *P* value	<.0001			
Exercise	Baseline	4.35 (0.24)			
	4 months	5.03 (0.24)	0.68	0.14, 1.22	.014
	8 months	4.41 (0.24)	0.07	–0.48 to 0.61	.812
	Trend *P* value	.026			
Blood glucose testing	Baseline	1.33 (0.24)			
	4 months	2.59 (0.24)	1.26	0.75, 1.76	<.0001
	8 months	1.78 (0.24)	0.46	–0.05 to 0.96	.076
	Trend *P* value	<.0001			
Foot care	Baseline	2.18 (0.19)			
	4 months	2.10 (0.19)	–0.08	–0.57 to 0.41	.747
	8 months	2.30 (0.19)	0.12	–0.37 to 0.61	.634
	Trend *P* value	.726			
Smoking	Baseline	0.57 (0.14)			
	4 months	0.13 (0.14)	–0.44	–0.76 to –0.13	.006
	8 months	0.14 (0.14)	–0.43	–0.74 to –0.11	.008
	Trend *P* value	.008			
Diabetes symptoms (Self-Completion Patient Outcome Instrument)					
Number of positive symptoms (from a list of 9)	Baseline	0.16 (0.11)			
	4 months	0.45 (0.11)	0.29	0.01, 0.57	.043
	8 months	1.04 (0.11)	0.88	0.60, 1.16	<.0001
	Trend *P* value	<.0001			
Occurrence frequency of diabetes symptoms (scale 0-100)	Baseline	1.56 (0.86)			
	4 months	4.14 (0.87)	2.58	0.35, 4.81	.024
	8 months	8.54 (0.87)	6.98	4.75, 9.21	<.0001
	Trend *P* value	<.0001			
Diabetes complications (7 categories)	Baseline	0.40 (0.07)			
	4 months	0.24 (0.07)	–0.16	–0.34 to 0.03	.091
	8 months	0.34 (0.07)	–0.06	–0.24 to 0.12	.508
	Trend *P* value	.234			

[a]Significance test of the linear trend of change over time.

*The time frame is every 4-month interval, i.e., the medical care used or laboratory test performed in the past 4 months. If no test was done during the specific time period, the most recent test result was carried forward.

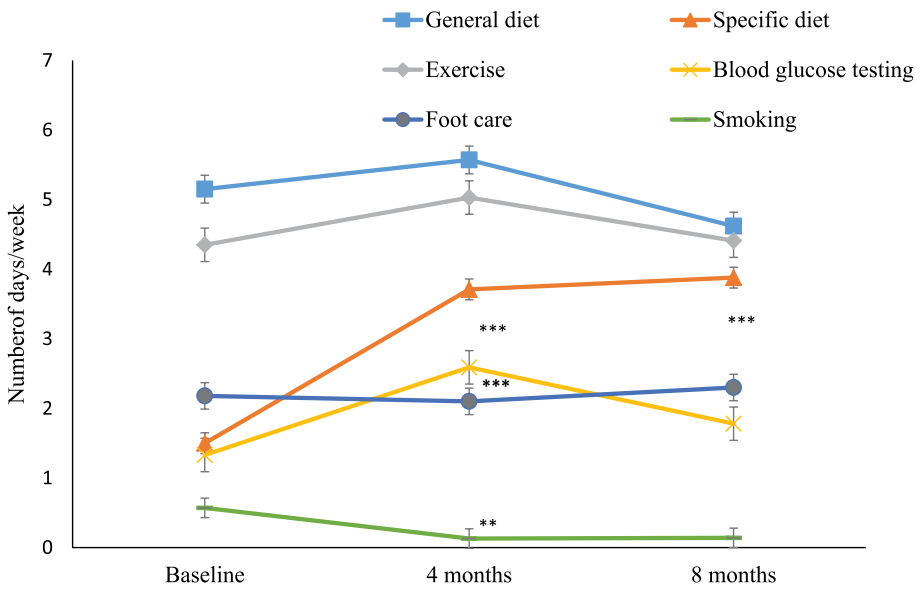

Figure 1. Diabetes self-care behavior change over the study period.
*$P < .05$. * $P < .01$. *** $P < .001$ compared to baseline.

benefit increased at 8 months (−6.92 mg/dL, 95% CI, −11.55 to −2.29, $P = .004$), resulting in a significant trend of change from baseline ($P = .014$). A1C decreased over the study period (0.12% and 0.15% on average at 4 and 8 months, respectively), but the change trend was not statistically significant ($P = .22$).

Discussion

This article reports the longitudinal efficacy of an mHealth intervention (IMTOP) encompass intergenerational support to encourage behavior change and utilized mobile technology to promote T2DM knowledge and enhance diabetes care in a rural area. The results showed that IMTOP intervention had significant and lasting effects on improving T2DM-related specific diet and smoking behavior. However, the initial increase observed in exercise habits was not maintained at the 8-month follow-up. The IMTOP mobile app relied on users to self-track their exercise. This passive approach was probably insufficient to sustain exercise gains over the program period. Previous studies have also reported that exercise improvement is difficult to maintain longitudinally.[26,27] Active mHealth approaches to encourage exercise, such as text messaging and exploiting wearable devices, may improve the sustainability of the program effects on physical exercise.[28-30]

Despite improvements in self-care behaviors, the number and occurrences of diabetes symptoms surprisingly increased at 4 and 8 months. One possible explanation for the increase in participants reported T2DM symptoms is that their self-awareness was raised by the diabetes self-management education and constant tracking of health conditions using IMTOP app. This seemingly unfavorable result may, in fact, be positive because it may reflect enhanced health awareness among patients. Population-based diabetes research in China pointed out the relatively low awareness and control rate of T2DM in rural population compared to their urban counterparts.[31] IMTOP could be implemented in rural settings to enhance T2DM awareness and literacy. In addition, it should be noted that although the changes in the reported number of symptoms and frequency were statistically significant, the extent to which symptoms change may not be clinically insignificant (eg, on a scale range from 0 to 100, the occurrence frequency of diabetes symptoms increased 6.98 at 8-month follow-up).

Patients had decreased fasting blood glucose and LDL cholesterol over the 8-month period. Within the clinically recommended range,[32] participants made fewer endocrinology clinic visits and spent less on medications compared with the baseline. These objective indicators show that the IMTOP intervention improved clinical outcomes and has the potential to alleviate the health

Table 3

Medical Care Utilization and Laboratory Test Results From Baseline to 4-Month and 8-Month Follow-Ups

Characteristic	Time[a]	Least Squares Mean (SE)	Change Score (Δ Since Baseline) Mean	95% CI	*P* Value
Medical care use, n = 97					
Total No. of clinic visits	Baseline	4.44 (0.49)			
	4 months	4.85 (0.49)	0.42	−0.30, 1.13	.253
	8 months	4.44 (0.49)	0.0004	−0.72, 0.72	.999
	Trend *P* value[b]	.418			
No. of endocrinology clinic visits	Baseline	1.56 (0.07)			
	4 months	1.16 (0.07)	−0.40	−0.57, −0.24	<.0001
	8 months	1.32 (0.07)	−0.24	−0.40, −0.08	.003
	Trend *P* value	<.0001			
Total cost of prescription medicines, USD	Baseline	376.43 (166.01)			
	4 months	426.72 (166.01)	50.29	−265.75, 366.33	.754
	8 months	169.75 (166.01)	−206.67	−522.71, 109.36	.199
	Trend *P* value	.238			
Cost of medicines prescribed by endocrinology clinic doctors, USD	Baseline	85.87 (7.54)			
	4 months	64.18 (7.54)	−21.69	−34.29, −9.09	.001
	8 months	74.44 (7.54)	−11.43	−24.04, 1.17	.075
	Trend *P* value	.004			
Laboratory tests					
Systolic blood pressure (mmHg), n = 37	Baseline	148.09 (4.44)			
	4 months	150.42 (4.27)	2.33	−3.47, 8.13	.424
	8 months	146.62 (4.15)	−1.47	−7.24, 4.30	.612
	Trend *P* value	.346			
Diastolic blood pressure (mmHg), n = 37	Baseline	84.62 (2.61)			
	4 months	85.05 (2.54)	0.44	−2.35, 3.22	.755
	8 months	82.31 (2.50)	−2.31	−5.08, 0.47	.101
	Trend *P* value	.076			
Fasting blood glucose (mg/dL), n = 94	Baseline	153.02 (4.83)			
	4 months	140.69 (4.83)	−12.33	−22.54, −2.12	.018
	8 months	144.10 (4.83)	−8.92	−19.13, 1.28	.086
	Trend *P* value	.051			
A1C (%), n = 94	Baseline	7.50 (0.12)			
	4 months	7.38 (0.12)	−0.12	−0.30, 0.06	.196
	8 months	7.35 (0.12)	−0.15	−0.33, 0.03	.097
	Trend *P* value	.219			

(continued)

Table 3

(continued)

Characteristic	Time[a]	Least Squares Mean (SE)	Change Score (Δ Since Baseline) Mean	95% CI	*P* Value
LDL cholesterol (mg/dL), n = 94	Baseline	90.98 (2.39)			
	4 months	87.26 (2.39)	–3.72	–8.36, 0.92	.115
	8 months	84.06 (2.38)	–6.92	–11.55, –2.29	.004
	Trend *P* value	.014			
HDL cholesterol (mg/dL), n = 92	Baseline	50.33 (1.43)			
	4 months	49.21 (1.43)	–1.11	–2.43, 0.21	.098
	8 months	49.60 (1.42)	–0.73	–2.05, 0.59	.279
	Trend *P* value	.244			
Triglycerides (mg/dL), n = 94	Baseline	130.57 (8.61)			
	4 months	133.94 (8.61)	3.37	–11.46, 18.19	.655
	8 months	139.40 (8.61)	8.83	–6.00, 23.65	.242
	Trend *P* value	.496			
Total cholesterol (mg/dL), n = 92	Baseline	158.03 (3.13)			
	4 months	152.45 (3.13)	–5.58	–11.01, –0.16	.044
	8 months	153.63 (3.13)	–4.40	–9.83, 1.02	.111
	Trend *P* value	.104			

Abbreviations: LDL, low-density lipoprotein; HDL, high-density lipoprotein.
[a]The time frame is every 4 months (ie, medical resources used or laboratory tests performed in the past 4 months). If no test were done during the specific time period, the most recent test result was used.
[b]Significance test of the linear trend of change over time.

care system overflow and reduce economic costs for patients in rural Taiwan. Although a decreasing trend in A1C was observed, the magnitude of change did not reach statistical significance level. A systematic review indicated only 3 out of 15 intervention projects with rural T2DM patients reported significant improvements in A1C.[15] A longer follow-up period was suggested to observe the impact on metabolism.[15] A meta-analysis of mHealth intervention for urban population found an improvement on A1C was only observed in those interventions that provided feedback for the participants' health information.[16] Although the participant recruitment was conducted in collaboration with a hospital, the current IMTOP design has not yet explored the specific role of a professional care team in the intervention and follow-up stages. To improve the IMTOP intervention, it is necessary to actively engage the health care team to provide feedback in the next study phase.

The IMTOP program has both strengths and weaknesses compared with existing interventions with rural T2DM patients. To the authors' knowledge, it is the first mHealth intervention that used a mobile app as an enabling tool and providing self-management knowledge and intergenerational support opportunities to mobilize rural older patients with T2DM to change health behaviors. Although the efficacy of in-person and telehealth intervention has been well documented, no previous study reported the effect of a mHealth intervention with a mobile app for the rural population.[15,17,33,34] Previous literature reported twice-weekly health voice messages sent to participants from rural Bangladesh and found no significant intervention effect on clinical outcomes and self-care behaviors.[17] The emphasis on intergenerational support and weekly in-person training is a strength of IMTOP that possibly made it effective. Nevertheless, the external validity of the study results is limited by the

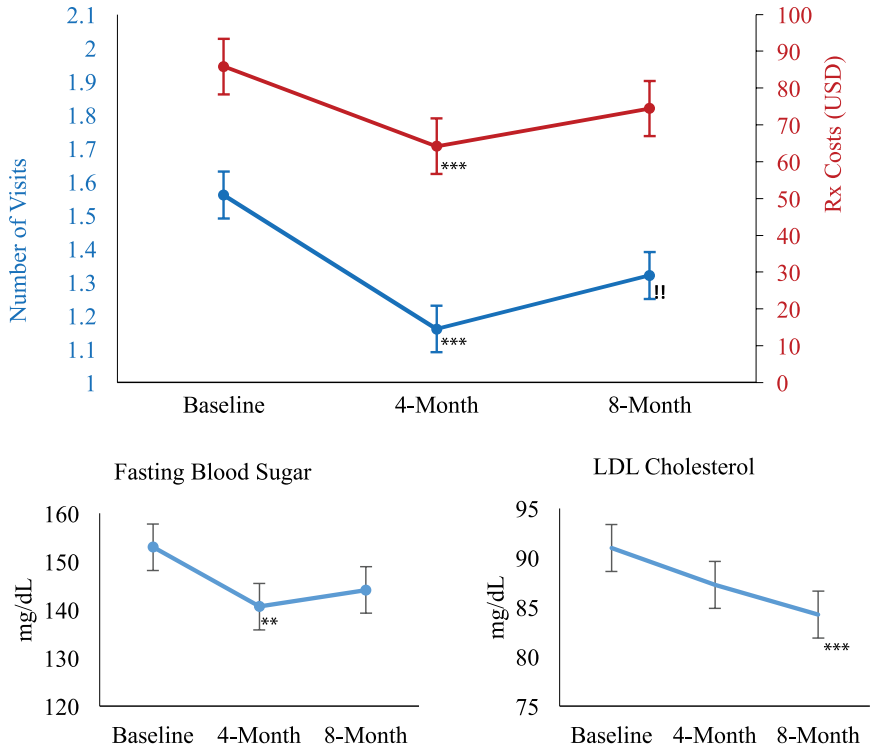

Figure 2. Endocrinology clinic visits, medication costs, and laboratory test results with significant changes over the 8-month follow-up period.
$^{**}P < .01$. $^{***}P < .001$ compared to baseline.
[a]Care used in the past 4 months based on medical records, mean (SE).

single-site design with a rather homogenous Chinese population. Participants who met the inclusion criteria were Chinese-literate and had means of transportation to the hospital. Lack of transportation would prevent individuals with more severe conditions and in greater need from participating. Future studies should investigate other forms of recruitment and/or interventions that are able to engage the most vulnerable groups.

In sum, the longitudinal results of the IMTOP intervention support the efficacy of a mHealth intervention for rural older patients with T2DM. The use of mobile technology to improve the quality of life of older adults with T2DM and the intergenerational training program are innovative components that have not been previously reported in the literature. IMTOP intervention offers a possible mHealth approach to address the disparity of rural health care by alleviating the increasing burden on the health care system and enabling rural older adults to conduct self-management. By bringing two generations together and building social capital for both groups, IMTOP not only has the potential to facilitate T2DM care for the current generation of the older adult but also curb the high prevalence rate in the future generations through volunteering learning. Whether the IMTOP approach would be feasible and acceptable for rural communities from other societies and cultural backgrounds also needs further empirical tests.

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