Impact of a Mobile Application Based Intervention on Improving Glycemic Control

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Abstract

Purpose

Diabetes often remains untreated in low-resource settings due to inadequate healthcare infrastructure and compromised mobility especially, for women. The Glucose Trail (GT) intervention was designed to manage diabetes in patients from a low resource setting via a mobile application and community mobilization. The primary objective of this study was to assess the impact of the intervention on glycemic control parameters. The secondary objective was to examine the change in blood pressure, BMI and waist circumference.

Methods

A retrospective review was conducted among patients included in the GT intervention conducted between February 2019 to August 2019 at a health-center in Pind Begwal, Pakistan. Patients with HbA1c > 6.5% (48mmol/mol) and FBG >126 mg/dL or random blood glucose >200 mg/dL were included. Patients with end-stage diabetes complications, advanced medical comorbidities requiring frequent hospitalization or lack of ambulation were excluded. Lady health workers, selected from the community, followed patients for 6 months via home visits. During each visit, the patient's FBG, waist circumference, weight and blood pressure were updated in the GT mobile application. The information was reviewed by a remote physician who titrated treatment. The updated plan was then conveyed to the patient by a lady health worker.

Results

44 patients were enrolled in Pind Begwal; 3 lost to follow-up. A decrease in HBA1c (p=0.026)), FBG (p=0.044), systolic blood pressure (p=0.044) and diastolic blood pressure (p=0.002) was recorded. There was an increase in average BMI (p=0.318) and decrease in waist circumference (p=0.511) compared to baseline values.

Conclusions

The GT application intervention improved glycemic control among patient from a low-resource setting. Further studies with a larger sample size are necessary to solidify this association.

Background

The prevalence of diabetes is increasing worldwide, with the greatest increases occurring in low and middle income countries, children, adolescents, and young adults [1, 2]. In Pakistan the prevalence was reported to be 16.98% in 2019, with approximately 48% of diabetes-related deaths occurring in individuals below 60 years [3]. Diabetes often remains untreated in low resources settings, especially in rural and

semi-urban areas, as a result of inadequate healthcare infrastructure and compromised mobility, especially, for women [4]. Due to a lack of available conventional therapies, traditional and homeopathic alternatives are often sought from unqualified individuals which often leads to detrimental health outcomes [5].

Tele-health app-based interventions show promise as an effective method for improving diabetic outcomes while circumventing the limitations of hospital-based practice [6–8]. However, most studies evaluating the effects of such interventions are based in high income countries like France, South Korea, Canada, Finland and Japan [6, 8] or geared towards individuals from wealthier social classes and younger age groups [7]. There is a paucity of knowledge on the effectiveness of app-based diabetic interventions in low-income rural and semi-urban settings. The Glucose Trail (GT) intervention was designed to manage diabetes in patients from a low resource setting with poor infrastructure facilities and digital literacy via a mobile application and community mobilization. The primary objective of this study was to assess the impact of the GT intervention on glycemic control parameters (HbA1c and fasting blood glucose (FBG)). The secondary objective was to examine the change in ancillary health parameters i.e. blood pressure, BMI and waist circumference.

Methods

Study design

A retrospective review was conducted among patients included in the GT intervention conducted between February 2019 to August 2019 at a health-center in Pind Begwal, Pakistan. The center is owned by Saving 9, a registered non-profit organization. Information regarding patient demographics (age, gender), number of follow-up visits, examination findings (weight, waist circumference, blood pressure, height) and lab results (HbA1c, FBG, random blood glucose (RBG), creatinine, eGFR) were collected. Ethical exemption to review unidentified information was obtained from Ethical Review Committee at the Aga Khan University. (Review reference number: 2020-5221-13953).

Application development

The application was designed to ensure compatibility with consumer literacy, app security and user privacy. To meet these criteria, design and development was conducted by a multidisciplinary research team including, experts in software development, data privacy and security, a graphical user interface designer and language editor, and a health professional. The app has three main features: (I) Entry and record of patient data (study identification number, age, gender, weight, height, waist circumference, blood pressure) and lab investigations (FBG, RBG, HbA1c, creatinine, eGFR); (II) review of data by a remote physician (III) entry of treatment plans (IV) privacy (no medical data leaves the device) and restricted access to patient information for users of the application. It was available on the Google Play Store for android mobile devices.

Community involvement

Lady health workers (LHW) from Pind Begwal (PB) who were literate in written English and owned a smart phone compatible with the application were selected. Three sessions were conducted to train them to measure FBG, RBG, height, weight, waist circumference and blood pressure, operate the GT application and relay the treatment plan to patients. Equipment required for measuring the aforementioned variables (glucometer, weighing scale and automatic blood pressure monitor) was provided to each LHW.

Patient recruitment

An advertisement campaign was conducted for the intervention through distribution of pamphlets at the health-center and through home visits by LHWs. Patients were requested to visit the healthcare center for study enrollment where convenience sampling and was used and consent obtained to recruit patients with an established diagnosis of diabetes defined as, HbA1c > 6.5 and FBG > 126mg/dL or RBG > 200 mg/dL. Patients with end-stage diabetes complications including end-stage renal disease, chronic heart failure, peripheral vascular disease leading to foot ulceration/ amputation, proliferative retinopathy, gestational diabetes, non-ambulatory patients and patients with advanced medical comorbidities requiring frequent hospitalization such as active cancer, advanced liver disease etc. were excluded.

The intervention

HbA1c, FBG, blood pressure, waist circumference, weight, height, creatinine, eGFR, comorbid conditions and the patient's current medications were recorded at the time of recruitment and entered into the application. A remote endocrinologist, licensed to practice in Pakistan, was selected to review patient information and prescribe appropriate treatment according to the guidelines.[9] he treatment plan was entered into the application was consisted of medication dose and frequency, diet and exercise recommendations and the next recommended follow-up appointment timing. The LHWs conveyed the treatment plan to the patient through a home visit or telephone call. The patients were then followed up via home visits for a period of six months. The frequency of visits for each patient was according to the discretion of the endocrinologist. The patient was also examined at each follow-up visit where fasting blood sugar, blood pressure, waist circumference, and weight were recorded and the updated measurements were recorded in the application.

Outcomes

The primary outcome consisted of glycemic control parameters including HbA1c and fasting blood glucose. Secondary outcomes included ancillary health parameters including BMI, weight, waist circumference and blood pressure.

Statistical analysis

All analysis was conducted using SPSS software version 22. Missing data from a visit was input with readings from the previous follow-up visit provided it occurred within one month. Mean, standard deviation and range of HbA1c, FBG, BMI, weight blood pressure and waist circumference was calculated for baseline and final readings. Due to high fluctuation in FBG readings, mean and standard deviation for

values in the final two months of the patient's participation were calculated for each patient and used as final values. Distribution of variables was assessed using the Shapiro Wilk test. Mean and standard deviation was calculated for normally distributed variable and a paired t-test was used to compare final and baseline variables. Median and interquartile range was calculated for variable without normal distribution. Wilcoxon signed rank test was used for comparison. P value below 0.0.5 was considered significant.

Results

Patient demographics

In PB, 48 patients met the inclusion criteria and 44 patients consented to participate. 3 subjects were lost to follow-up during the trial. The remaining population had a male:female ratio of 7:34 with mean age 51.82 ±13.04 years; ranging from 29-80 years. The mean follow-up time (including trial phase) for each patient was 9.3±1.2 months with a range of 7-13 months during which, each patient received an average of 25±5 follow-up visits. (Table 1).

Table 1
Demographics for patients included in a retrospective review of an application-based telemedicine intervention on improving glycemic control

Demographics	
No. of patients (n)	44
Loss to follow-up (n)	3
male:female ratio	7:34
Age (years ± SD)	51.82 ± 13.04
Follow-up time (months ± SD)	9.3 ±1.2
Source: Glucose Trail app; Abbreviations: SD=standard deviation,	

Creatinine and eGFR

Patients in PB had a baseline Creatinine of 0.853±0.282 mg/dL ranging from 0.56 mg/dL-1.88 mg/dL (normal range: 0.5-1.0 mg/dL) and eGFR of 84.500±21.744 mL/min/1.73m^2 ranging from 28.0-122.0mL/min/1.73m^2 (normal range: greater than 90mL/min/1.73m^2).

HbA1c

In PB, the baseline average HbA1c was 10.41% (90 mmol/mol) with 37 (90%) patients with HbA1c exceeding 7.0% (53 mmol/mol). Mean initial HbA1c was 10.4 ± 2.3 and decreased in 25 patients with final mean value of 9.6 ± 2.1 (p=0.026) (Table 2). Final readings showed that 37 (90%) patients had

HbA1c above 7% (53 mmol/mol). Patients with decrease in HbA1c received an average of 25 sessions with their LHW.

Fasting blood glucose

In PB, FBG level was measured an average of 28±7 times per patient with a range of 17-42 times. Average FBG blood level was 254 ± 78 mg/dL at baseline and 226 ± 62 mg/dL at final readings (p=0.004). (Table 2)

Table 2
Primary and secondary outcomes of patients in included in a retrospective review of an application-based telemedicine intervention on improving glycemic control

Parameter	Initial values	Final values	p value
Primary outcome			
Fasting blood glucose (mg/dL) (mean ± SD; range)	235.9 ± 77.9; 132 - 510	225.7 ± 62.2; 140 - 356	0.004
HbA1c (%) (mean ± SD; range)	10.4 ± 2.3; 6.0 - 16.9	9.6 ± 2.1; 5.8 – 14.0	0.026
Secondary outcomes			
Systolic blood pressure (mmHg) (mean ± SD; range)	140.54 ± 22.67; 104-199	132.07 ± 23.19; 95 - 187	0.044
Diastolic blood pressure (mmHg) (median (IQR); range)	84.00 (77.5 – 97.5) 73 - 111	80.0 (73.50 – 87.50); 57 - 122	0.002
Weight (kg) (mean ± SD; range)	68.02 ± 10.66; 45-90	69.22 ± 11.51; 45 - 94	0.127
BMI (kg/m^2) (mean ± SD; range)	27.71 ± 4.54; 18 - 39	28.12 ± 4.99; 18 - 40	0.318
Waist circumference (cm) (median (IQR); range)	100 (93 - 97); 53 - 150	99 (92.5 - 108); 53 – 126	0.135
Source: Glucose Trail app; SD=Standard Deviation			

BMI, weight, waist circumference and blood pressure

In PB, there was a significant decrease in mean systolic (p=0.044) and diastolic (p=0.002) blood pressure levels. There was a non-significant increase in BMI (p=0.318) and weight (p=0.127), and decrease in waist circumference (p=0.135) compared to baseline values. (Table 2)

LHW performance

Eight LHWs were trained in PB and three withdrew during the course of the project. The remaining LHWs were assigned 11, 14, 9, 5 and 2 patients respectively. LHW performance was assessed by comparing

changes in HbA1c and FBG levels in the patients assigned to each LHW; differences were present but were non-significant (p=0.063). (Table 3)

Table 3
Change in parameters of patients under the care of each healthcare companions in Pind Begwal.

HCC Performance		
HCC	**HbA1c percentage dec. (%) (mean ± SD)**	**FBG percentage dec.(%) (mean ± SD)**
HCC 1	8.26 ± 9.94	3.28 ± 20.27
HCC 2	-3.29 ± 24.35	4.42 ± 21.70
HCC 3	11.02 ± 13.76	19.64 ± 14.94
HCC 4	5.93 ± 7.18	7.76 ± 25.24
HCC 5	33.85 ± 26.87	12.56 ± 10.78
Source: Glucose Trail app; Abbreviations: HCC=healthcare companion; dec.=decrease; SD= standard deviation		

Discussion

The GT intervention is a novel digital healthcare approach implemented in a low resource setting with limited access to healthcare. There was a significant improvement in glycemic control parameters. The improvement in glycemic control is consistent with application based diabetic interventions conducted in previous studies. A systematic review analyzing app based interventions, showed an improvement in glycemic control among type 2 diabetics in all studies with mean reduction in HBA1c ranging from (0.15 to 1.87%) [8]. In India, the intervention group of the mHealth Gather System saw a statistically significant decrease in HBA1c of 1.5% from an initial mean HBA1c of 9% [7].

A significant decrease was seen in blood pressure showed a significant decrease in mean systolic and diastolic levels. This is consistent with other studies which show that improved glycemic control helps to reduce blood pressure [7]. Mobile applications have been shown to encourage compliance with regular blood pressure monitoring.[10]

The intervention overcame the need for technological literacy among patients by supplementing app-based communication with LHWs recruited from with the community and resulted in an improvement in glycemic control. By contrast, for other mobile application interventions, literacy and technological adeptness are prerequisites for the populations on which can be applied. Another major strength of this intervention was its ability to build a local network by encouraging local participation in the health of the community. LHWs in PB were recruited from within the community and had ties to the patients they were overseeing. These community ties between LHWs and patients in PB may have contributed to an increased motivation among LHWs to help patients and patients' acceptance of LHWs involvement in their care. Moreover, it was able to create sustainable change and increase local understanding of issues.

The study methodology lends itself to certain limitations on the generalizability of its results. The sample size was small. The absence of a control group made it difficult to definitively assess whether changes in glycemic control parameters were due to the intervention or confounding variables and an observation bias. The intervention heavily relies on LHWs so its impact is affected by the quality of care they provide. Therefore, a standardized rubric is necessary for a quantitative assessment of their performance and training strategies.

In conclusion, the Glucose Trail intervention shows promise for future mobile application based healthcare interventions in low-resource communities in Pakistan and similar demographic regions. It encourages the fusion of traditional community mobilization methods with technological interventions towards better healthcare management and improved glycemic outcomes. Although further studies with more rigorously designed interventions are needed to solidify this association. It serves as a starting point for mobile application based interventions in Pakistan.

Conclusions

The GT application intervention improved glycemic control among patient from a low-resource setting. Further studies with a larger sample size are necessary to solidify this association.

Declarations

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interests

The authors declare no potential conflict of interest relevant to this article.

Authors' contributions

All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work, and have given their approval for this version to be published. Wardah Rafaqat (WR) conceived and designed the study; Sameer

Mohiuddin Belgaumi (SMB), Maeen Abbas Syed (MAS) and WR performed data analysis and prepared the manuscript; Rafay Iqbal (RI) critically reviewed the manuscript.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Ethical exemption to review unidentified information was obtained from Ethical Review Committee at the Aga Khan University. (Review reference number: 2020-5221-13953).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent to publish

The authors affirm that human research participants provided informed consent for publication of data included within the manuscript.

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