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Research Article

Drug interaction detection and glycemic control – telepharmacy's role in diabetes management: before-after study

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Abstract

Introduction: Diabetes management faces intertwined challenges like polypharmacy and adherence complexities, hindering effective care delivery. Telepharmacy emerges as a promising solution, revolutionizing diabetes care by enhancing pharmacists' pivotal role. However, a tailored model for Indonesia is still lacking.

Purpose: This study aimed to assess the potential effectiveness of a telepharmacy application in improving the detection of drug-drug interactions and glycemic control.

Methods: We conducted an observational before-and-after study among type 2 diabetic patients in Indonesia.

Results: We noted a significant surge in detected drug interactions. Patients counseled through telepharmacy had 3.653 times higher likelihood of achieving good glycemic control.

Conclusion: The study underscores the positive impact of telepharmacy on drug interaction detection and glycemic control among Indonesian diabetics.

Keywords

Drug interaction, glycemic control, telepharmacy, pharmacist, diabetes management

Introduction

Diabetes management faces many interrelated challenges, particularly polypharmacy, where the intricate nature of diabetes prompts the concurrent use of multiple medications (Alwhaibi et al. 2018; Bui et al. 2021; Hickman et al. 2023; Koto et al. 2023; Lisni et al. 2023). Polypharmacy increases the risk of drug-drug interactions, spanning from mild to severe, compromises treatment efficacy and jeopardizes patient safety (Marengoni and Onder 2015; Sheikh-Taha and Asmar 2021). Furthermore, patients often grapple with adherence issues due to complex medication schedules, side effects, and lifestyle adjustments

during treatment (Gast and Mathes 2019; Lee and Lee 2022). Non-adherence not only escalates healthcare costs and complications risks but also exacerbates the complexity of polypharmacy and potential interactions (Fukuda and Mizobe 2017; Taha et al. 2022). Essentially, the complex interrelationship between polypharmacy, drug interactions, and low adherence undermines effective diabetes management; thus, posing substantial challenges to healthcare providers.

In diabetes management, pharmacists play a crucial role in optimizing the appropriateness and safety of treatment regimens (Smith 2009; Knezevich et al. 2022). Their expertise enables detection and mitigation of drug interactions, thereby reducing polypharmacy-related risks (Knezevich et al. 2022). In addition, pharmacists serve as educators and counselors to patients, educating them on adherence, lifestyle modifications, and self-care practices to encourage patient understanding and informed decisions (Campbell 2002). Their multifaceted role encompasses medication management, patient education, and collaboration with healthcare teams, which significantly enhances patient outcomes (Campbell 2002; Knezevich et al. 2022).

However, pharmacists face several constraints that limit their ability to provide comprehensive care. Having multiple responsibilities, such as medication dispensing, administrative tasks, and managing high patient volumes, limits time for engagement in patient education and counseling (Meade et al. 2018). Staff shortages exacerbate this problem, overwhelming pharmacists and preventing tailored care provision (Eshbair et al. 2022). Technological limitations further hinder efficient medication management ((Moore et al. 2020; Eshbair et al. 2022), as some settings lack integrated patient data access or advanced tools for drug interaction detection, hampering thorough reviews and comprehensive care delivery.

To overcome these constraints, telepharmacy is revolutionizing diabetes care. Digital platforms centralize patient data, providing pharmacists with comprehensive information to conduct thorough medication reviews and detect interactions (Poudel and Nissen 2016; Baldoni et al. 2019). It also extends pharmacist reach beyond physical locations, allowing remote consultations for counseling and medication management, bypassing scheduling constraints (Iftinan et al. 2021; Tjiptoatmadja and Alfian 2022). This innovation holds immense significance in an archipelagic nation like Indonesia. In addition, telepharmacy optimizes staff utilization, in order to serve a larger patient base and ensure broader access to care (Baldoni et al. 2019).

Telepharmacy emerges as a promising innovation bridging gaps in healthcare delivery, including diabetes management (Crossen et al. 2022). Notably, existing literature supports its positive impact on diabetes care, demonstrating improvements in clinical parameters (Iftinan et al. 2021; Cao et al. 2022). However, within the context of Indonesia, a significant gap persists-a lack of a tailored telepharmacy model designed explicitly for diabetes management.

Therefore, this study aimed to address this gap by introducing a novel telepharmacy application specifically tailored for diabetes care. Through its development and preliminary evaluation, this study aimed to determine whether this intervention can significantly improve drug interaction detection and glycemic control among Indonesian diabetes patients. This exploration holds the potential to revolutionize diabetes care paradigms in Indonesia and offers a proactive solution to the challenges encountered in conventional diabetes management approaches.

Methods

This study adhered to the reporting guidelines outlined in the STROBE statement (von Elm et al. 2007; Cuschieri 2019), elucidated further in Suppl. material 1 of the supplementary material.

The development of telepharmacy application

We partnered with an information technology developer (Indonesia Test & Telepharmacy or InaTTI) to pioneer the development of a telepharmacy application tailored for diabetes patients. For the drug interaction checker, we initially established the anti-diabetes medication based on Indonesia's diabetes therapy guidelines, specifically the Guidelines for Management and Prevention of Type 2 Diabetes Mellitus in Adults in Indonesia Year 2021. We searched https://cekbpom.pom.go.id to verify the availability of these anti-diabetes drugs. Subsequently, these anti-diabetes medications were assessed for potential drug interactions, their effects, severity levels, and recommendations for managing these effects using available drug interaction checker applications such as Drugs.com, Micromedex, and Drug Bank.

Once the database was organized, we integrated the drug interaction checker with the InaTTI telepharmacy application. This telepharmacy application is already linked to the patient medication record and patients' WhatsApp accounts. Consequently, whenever we input the names of anti-diabetes medications and other drugs from a prescription, the telepharmacy application promptly notifies us about potential drug interactions, their effects, severity levels, and recommended ways to manage these interactions. Moreover, the telepharmacy application sends notifications to patients via WhatsApp, prompting them to engage in counseling sessions through telepharmacy.

Study design and setting

This was an observational before-and-after study conducted at Muhammadiyah Hospital, a private secondary care hospital located in the capital of the most populous province in Indonesia. We prospectively studied prescriptions among type 2 diabetes (T2D) patients in the Prolanis program. Prolanis is an integrated health service initiative, which aimed to manage clinical and laboratory outcomes, prevent complications, and enhance the quality of life for patients with diabetes and hypertension (Alkaff et al. 2021).

Participants

This study examined changes in outcomes following the use of a digital product designed to manage health conditions (Office for Health Improvement and Disparities 2020). We observed different groups of participants before and after the implementation of telepharmacy without intervening in participant assignments or controlling the exposure. The two-different-group approach was chosen due to the dynamic nature of our initial sample, which consists of prescriptions.

The inclusion criteria were prescriptions of T2D patients aged 18 or older who sought outpatient treatment. Employing a total sampling method, we focused to emphasize potential drug interactions within polypharmacy scenarios. Therefore, prescriptions with fewer than five drugs were excluded (WHO 2019). Pre-telepharmacy data were collected in April 2023 for drug-drug interactions and in May and June 2023 for fasting blood glucose (FBG) levels. Post-telepharmacy data were collected in August 2023 for drug-drug interactions and in September and October 2023 for FBG levels. Patients without FBG level data in glycemic control evaluation were also excluded.

Ethical approval

The Research Ethics Committee of the University of Padjadjaran approved this study (No. No.195/UN6.KEP/EC/2023). Written informed consent was obtained from all patients. We ensured their privacy and anonymity during data collection and analysis.

Before-telepharmacy group

In the before-telepharmacy group, we prospectively examined the prescriptions of eligible patients before the implementation of the telepharmacy application (April 2023). During this phase, potential drug interactions were manually identified using Medscape, and medication was dispensed according to standard procedures. Counseling in this group was given using the conventional (a one-to-one offline) method. In May and June 2023, we collected data on patients' FBG levels. We collected this data only twice because, in the subsequent months, Prolanis patients were typically referred back to primary care facilities. Patients who did not attend follow-up appointments during this period could not have their FBG measured;thus, they were excluded from the glycemic control evaluation.

After-telepharmacy group

After the introduction of the telepharmacy application (August 2023), the prescriptions of eligible patients were prospectively reviewed. Using the application, we identified potential drug interactions and dispensed medications as usual. Before patients departed, we inquired whether they agreed to participate in telepharmacy counseling. Patients who provided consent were instructed to create an account and log in to access the telepharmacy counseling sessions, which were conducted via WhatsApp. These sessions were facilitated by trained pharmacists who underwent specific training, ensuring that they met the necessary qualifications for delivering counseling services as per the guidelines. These counseling sessions occurred in August and September 2023. Subsequently, we collected data on patients' FBG levels in September and October 2023.

Finally, patients who received telepharmacy counseling were requested to complete a satisfaction questionnaire using Google Forms. Consenting patients were presented with five Yes/No questions concerning the application's ease of access, convenience of use, and time-saving, knowledge enhancement, and perceived health benefits.

Outcomes

The initial primary outcome of this study focused on identifying potential drug-drug interactions (pDDIs). We aimed to compare the number of pDDIs detected manually using Medscape and those detected using the application. We anticipated that using the application would enhance the number of pDDIs detected due to its comprehensive database constructed from diverse sources. However, assessing the severity of these interactions was a challenge because it is intricately linked to the medications prescribed to individual patients.

The secondary outcome focused on glycemic control, which was assessed by measuring FBG levels twice. A controlled FBG level was defined within the range of 70–110 mg/dL (American Diabetes Association 2021). We further categorized the FBG levels as either controlled or uncontrolled based on this cut-off. The FBG trends between patients who received telepharmacy counseling and those who did not were compared. We expected that patients who received telepharmacy counseling would demonstrate a higher likelihood of achieving controlled FBG levels than those who did not.

Data analysis

We conducted descriptive analysis to illustrate the frequencies and percentages of categorical data, while we presented mean ± standard deviation or median (range) for continuous data. The characteristics of both prescriptions and patients between the groups were compared. We used an independent sample t-test (for parametric data) or Mann-Whitney U test (for non-parametric data) for continuous data, while we conducted Chi-square tests for categorical data.

To evaluate significant differences in the number of detected pDDIs, we compared the average of each group employing either an independent sample t-test (for parametric data) or the Mann-Whitney U test (for non-parametric data). In examining the relationship between the implementation of telepharmacy counseling and glycemic control, we used Chi-square and multivariable logistic regression analysis to consider variables such as sex and age concurrently. We employed listwise deletion to handle

missing age and sex data, as the missing occurred completely at random (Kang, 2013). Moreover, the proportion of missing values accounted for less than 5% of the dataset, thus deemed inconsequential (Dong and Peng 2013). All statistical tests were two-tailed, with a significance level set at p<0.05. These analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., New York, USA).

Results

Participants' characteristics

This study examined 250 and 255 prescriptions in the before and after-telepharmacy groups, respectively. Roughly 62% of patients in both groups were elderly (aged 60 years or more), and approximately 56% were women. More than 70% of prescriptions in both groups comprised 5–7 drugs. There were no significant differences in the characteristics of the prescriptions between the two groups. Table 1 provides an overview of the studied prescription characteristics.

Table 1. Characteristics of the studied prescriptions in both before and after the implementation of telepharmacy.

Characteristics	Before group (n = 250)		After group (n = 255)		p-value[a]
	n	%	*n*	%	
Age (years), mean ± SD[b]	62.70 ± 9.85		61.95 ± 9.45		0.389[c]
Non-elderly	89	35.6	85	33.3	0.705[d]
Elderly (≥60 years)	155	62.0	159	62.4	
Missing	6	2.4	11	4.3	
Sex					
Men	94	37.6	108		0.474[d]
Women	142	56.8	143		
Missing	14	5.6	4		
Number of drugs per prescription, median (range)	6 (5–11)		6.5 (5–11)		0.116[e]
5–7	196	78.4	187	73.3	0.167[d]
8–10	52	20.8	63	24.7	
>10	2	0.8	5	2.0	

[a]The difference between the groups was significant at $p < 0.05$; [b]SD, standard deviation; [c]using independent sample t-test; [d]using Chi-square test; [e]using Mann-Whitney U test.

Regarding glycemic control evaluation, follow-up appointments were attended by 207 patients in the before-telepharmacy group, while 178 patients in the after-telepharmacy group consented to receive counseling. Both groups mainly consisted of elderly (>60%) and women (>55%). Most of the patients in both groups were prescribed 5–7 drugs. Notably, there were no significant differences between the groups, as shown in Table 2.

The impact of telepharmacy on drug interaction detection

Table 3 compares the number of drug interactions detected prior to and after telepharmacy implementation.

Table 2. Characteristics of patients in glycemic control evaluation.

Characteristics	Before group[a] (n = 207)		After group[b] (n = 178)		p-value[c]
	n	%	*n*	%	
Age (years), mean ± SD[d]	62.41 ± 9.89		61.92 ± 9.75		0.631[e]
Non-elderly	75	36.2	65	36.5	0.866[f]
Elderly (≥60 years)	128	61.8	107	60.1	
Missing	4	1.9	6	3.4	
Sex					
Men	80	38.6	75	42.2	0.517[f]
Women	121	58.5	99	55.6	
Missing	6	2.9	4	2.2	
Number of drugs per prescription, median (range)	6 (5–11)		6.5 (5–11)		0.097[g]
5–7	164	79.2	128	71.9	0.244[f]
8–10	41	19.8	48	27.0	
>10	2	1.0	2	1.1	

[a]Consisted of those attending follow-up appointments before-telepharmacy implementation; [b]consisted of those consenting to receive telepharmacy counseling; [c]the difference between groups was significant at $p < 0.05$; [d]SD, standard deviation; [e]using independent sample t-test; [f]using Chi-square test; [g]using Mann-Whitney U test.

Table 3. The number of detected drug interactions before-and-after telepharmacy implementation.

The number of drug interactions detected	The number of prescriptions	
	Before group	After group
0	55	23
1	67	31
2	54	27
3	30	29
4	21	36
5	9	30
6	5	18
7	4	15
8	0	14
9	3	11
10	0	7
11	1	4
12	0	5
13	0	3
15	1	1
18	0	1
Total	250	255

Due to the non-parametric distribution of the data, we compared the median number of potential drug interactions between the two groups. The median (range) was 2 (0–15) and 4 (0–18) for the before and after-telepharmacy groups, respectively. The Mann-Whitney U test found significantly more drug interactions detected in the after-telepharmacy group than in the before-telepharmacy group (p = 0.000).

The impact of telepharmacy on glycemic control

The descriptive analysis suggests that the number of patients achieving controlled FBG levels was higher in the group who received telepharmacy counseling than

that who did not. The percentages of patients with controlled FBG levels were 12% and 32% in the before- and after-telepharmacy groups, respectively. Furthermore, Table 4 shows the results from both bivariate and multivariable analyses exploring the correlation between telepharmacy counseling and glycemic control and other associated factors. Chi-square tests indicated a potential association between the provision of telepharmacy counseling and glycemic control. As the variable "sex" demonstrated a p-value below 0.25, it was included in the multivariable logistic regression model (Zhang 2016). The multivariate regression showed that patients receiving telepharmacy counseling were 3.653 times more likely to achieve controlled FBG levels than those receiving conventional counseling after adjusting for sex ($p = 0.000$). There were no significant difference between age and glycemic control.

Patients' satisfaction

Of the 178 patients who agreed to receive telepharmacy counseling, only 138 (77.5%) consented to complete the satisfaction questionnaire; their responses are detailed in Table 5. Over 90% of patients answered affirmatively ("Yes") to each question. Notably, most of the patients expressed that using counseling services via the InaTTi application saved them time on hospital commutes (97.8%). However, the highest frequency of "No" responses was observed for the question regarding the ease of accessing counseling through the InaTTi application (7.2%).

Discussion

Our study introduces a novel telepharmacy application tailored specifically for diabetes care, aiming to mitigate the challenges in the management of diabetes. Through its integration with advanced drug interaction checker functionalities, this application demonstrated remarkable efficacy in significantly enhancing the detection of potential drug interactions compared to manual assessments. This finding highlights the transformative potential of telepharmacy in augmenting pharmacists' capabilities, particularly in identifying and managing complex drug interactions associated with polypharmacy in diabetes treatment.

Specifically, the rate of drug interaction detection was significantly higher in the after-telepharmacy implementation group than in the before-telepharmacy group ($p < 0.05$). Although the data were obtained from different populations, we inferred that there was minimal divergence in clinical conditions, as all participants were enrolled in the Prolanis program. Studies have confirmed that comorbidity among T2D patients in the Prolanis program typically includes hypertension (Alkaff et al. 2020; Salamah et al. 2023). It highlights the potential tangible benefits of the telepharmacy model in identifying and addressing potential drug interaction risks, thereby enhancing the safety and appropriateness of the treatment regimens administered to these patients. Several studies corroborate this evidence, highlighting the beneficial impact of digital applications in detecting drug-drug interactions, ultimately enhancing patient safety (van Puijenbroek et al. 2000; Feng et al. 2020; Han et al. 2022).

Table 4. Results from bivariate and multivariable analyses exploring the correlation between telepharmacy counseling and glycemic control.

Characteristics	Bivariate[a]		*p*-value[d]	Multivariable[b]	
	Uncontrolled FBG level[c] *n* (%)	Controlled FBG level[c] *n* (%)		Odds ratio (95% CI[e])	*p*-value[f]
Have received telepharmacy counseling					
No	182 (87.9)	25 (12.1)	0.000	Ref.	0.000
Yes	121 (68.0)	57 (32.0)		3.653 (2.130–6.264)	
Age					
Non-elderly	110 (78.6)	30 (21.4)	0.972	–	–
Elderly (≥60 years)	185 (78.7)	50 (21.3)		–	
Sex					
Men	117 (75.5)	38 (24.5)	0.169	Ref.	0.212
Women	179 (81.4)	41 (18.6)		0.72 (0.430–1.207)	

[a]Using Chi-square test; [b]using binary logistic regression; [c]FBG, fasting blood glucose (categorized as controlled within 70–110mg/dL); [d]variables with a *p*-value of <0.25 were incorporated into the multivariable logistic regression model; [e]CI, confidence interval; [f]$p < 0.05$ is considered statistically significant

Table 5. Patients' satisfaction with telepharmacy counseling ($n = 138$).

No.	Questions	Yes	No
		n (%)	*n* (%)
1.	Did you find it easy to access counseling through the InaTTi application?	128 (92.8)	10 (7.2)
2.	Did you find using the counseling service through the InaTTi application convenient to use?	133 (96.4)	5 (3.6)
3.	Did you find that using counseling services through the InaTTi application saved you time from traveling to the hospital?	135 (97.8)	3 (2.2)
4.	Did you experience an increase in knowledge regarding your treatment while receiving counseling through InaTTI?	132 (95.7)	6 (4.3)
5.	Did you feel any health benefits for you during counseling using the InaTTi application?	131 (94.9)	7 (5.1)

This study also revealed a compelling correlation between telepharmacy counseling and improved glycemic control among diabetes patients. Those who engaged in telepharmacy counseling sessions exhibited a notably higher likelihood of achieving controlled FBG levels. This association emphasizes the pivotal role of patient education and remote counseling facilitated by the application in positively influencing health outcomes, potentially reducing long-term complications related to uncontrolled diabetes. The result aligns with those from prior research, such as a double-blind randomized controlled trial (RCT) in Turkey, a prospective-single cohort in Saudi Arabia, and a randomized trial in Denmark, which consistently demonstrated the positive impact of digital health technologies on glycemic control among individuals with diabetes (Rasmussen et al. 2016; Duruturk and Özköslü 2019; M Tourkmani et al. 2023).

In this study, patients expressed satisfaction with various aspects of the telepharmacy counseling application, especially time-saving, convenience of use, and knowledge enhancement. Similarly, a study in Spain found that diabetic patients reported high satisfaction with these aspects following telemedicine services (Rodríguez-Fortúnez et al. 2019). While the overall patient satisfaction with the telepharmacy services was high, insights gleaned from patient feedback indicated room for enhancement. Specifically, concerns regarding the ease of access to counseling sessions through the application surfaced as an area for potential improvement. Moreover, the study in Spain noted a need to enhance the accessibility of telemedicine (Rodríguez-Fortúnez et al. 2019). The study in India agreed, reporting that not all patients found digital health technology easy to access (Anjana et al. 2020). Recognizing that high satisfaction correlates with improved adherence (Hamasaki 2022), addressing this aspect could not only significantly enhance user experience but also promote more widespread and effective utilization of telepharmacy services, ultimately contributing to improved patient outcomes.

This study's strengths encompass a tailored intervention designed explicitly for Indonesian diabetes management, addressing a critical healthcare gap. By using a before-and-after approach, it offers practical insights into the real-world application of the telepharmacy model within the local healthcare system. Quantifiable outcomes, specifically in drug interaction detection and glycemic control, underscore its clinical relevance. The study's promising outcomes signal the potential for a substantial impact on patient safety and treatment efficacy in Indonesia's diabetes care. Moreover, the model's adaptability hints at scalability, suggesting broader applicability beyond the study's specific context and potential benefits for diverse healthcare settings.

However, this study has some limitations. Firstly, its design as a before-and-after study, lacking the rigorous control of an RCT, might introduce biases or confounding variables. The observational nature of the study restricts our ability to infer causal relationships. The relatively short duration of the study limits insights into sustained effects, warranting a longer follow-up period. In addition, limitations linked to sample size and participant characteristics may restrict the study's representativeness and robustness, calling for a more extensive and diverse sample. Overlooking factors, such as the duration of diabetes, comorbidities, and dietary or lifestyle changes, as well as ignoring technological constraints in varied healthcare settings, could further impact the study's comprehensiveness and generalizability.

Future research should encompass RCTs to strengthen causal inferences and minimize biases or confounders, while longitudinal studies are crucial for gaining insights into sustained intervention effects. To enhance study representativeness, robustness, and comprehensiveness, researchers should use diverse and larger populations, considering detailed patient profiles, including factors such as the duration of diabetes, comorbidities, and lifestyle changes. In addition, comprehensive assessments of technological and economic aspects, along with patient-centric approaches, will contribute to the improved application and understanding of telepharmacy in diabetes management.

Conclusions

The study underscores the positive impact of telepharmacy on drug interaction detection and glycemic control among Indonesian diabetes patients. The rate of drug interaction detection was significantly higher in the after-telepharmacy group than in the before-telepharmacy group, and patients receiving telepharmacy counseling were more likely to achieve controlled fasting blood glucose levels than those receiving conventional counseling. While we acknowledge the potential drawbacks of the study design, we contend that these research findings can serve as a foundation for understanding how telepharmacy can transform diabetes management and improve patient outcomes across various settings. Future research should aim for randomized controlled trials and longitudinal study designs with diverse and larger populations and should aim to assess technological feasibility and consider patient-centric approaches.

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Supplementary material 1

Drug interactions detection and glycemic control -telepharmacy's role in diabetes management: before-after study

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