The Impact of the Health Belief Model on Hypoglycemia Prevention Skills in Diabetes Mellitus Patients

Abstract

Aims: This research aimed to evaluate the effectiveness of educational interventions based on the Health Belief Model (HBM) in enhancing hypoglycemia prevention skills among individuals with diabetes mellitus (DM).

Materials & Methods: A quasi-experimental study design was utilized, incorporating a two-group pre-test and post-test framework. 72 participants were recruited through purposive sampling and divided equally into intervention and control groups, with 36 individuals in each. The intervention group received education through an HBM-guided mobile application, while the control group utilized a pocketbook for educational purposes. Participants' skills in preventing hypoglycemia were assessed before and after a two-month intervention period using a validated questionnaire. Data were analyzed using paired and independent t-tests, with statistical significance set at $p<0.05$.

Findings: The intervention group demonstrated a notable improvement in hypoglycemia prevention skills, with mean scores increasing from 48.11±6.17 at baseline to 55.89±6.92 post-intervention ($p=0.0001$). In contrast, the control group showed only a modest increase, from 43.17±4.75 to 45.39±5.93 ($p=0.0001$). Post-intervention comparisons revealed a statistically significant difference in skill levels between the two groups ($p=0.0001$).

Conclusion: The HBM-based education model effectively improved the ability of DM patients to prevent hypoglycemia. This technology-based intervention can serve as an innovative approach to health education for DM patients.

Keywords

Diabetes Mellitus [https://www.ncbi.nlm.nih.gov/mesh/68003920];
Hypoglycemia [https://www.ncbi.nlm.nih.gov/mesh/68007003];
Health Belief Model [https://www.ncbi.nlm.nih.gov/mesh/2052026];
Health Education [https://www.ncbi.nlm.nih.gov/mesh/68006266];
Mobile Health [https://www.ncbi.nlm.nih.gov/mesh/68017216];
Technology-Based Intervention

Introduction

Diabetes mellitus (DM) refers to a collection of metabolic conditions marked by persistent hyperglycemia caused by impaired insulin secretion, action, or both [1, 2]. As of 2021, diabetes affects over 537 million people globally, with this number expected to climb to 643 million by 2030 and 783 million by 2045. The prevalence of DM, diagnosed by medical professionals in individuals aged 15 and above, has consistently risen over the years, increasing from 1.5% in 2013 [1] to 2.0% in 2018 [2], and reaching 2.2% in 2023 [3].

Insulin therapy often leads to hypoglycemia, a condition resulting from an insulin dose that exceeds the patient's physiological needs, causing a significant drop in blood sugar levels. Additionally, hypoglycemia may arise from the failure of counterregulatory mechanisms, which can occur as a consequence of long-term diabetes mellitus [4]. It is the most common complication among diabetes mellitus patients, with approximately 90% of those receiving insulin therapy reported to have experienced hypoglycemic episodes [5].

Preventing hypoglycemia requires improved blood glucose control and early detection of the condition. This includes educating patients about the signs and symptoms of hypoglycemia, as well as immediate steps for temporary management [6, 7]. Knowledge and understanding of hypoglycemia are crucial for identifying its onset, interpreting early symptoms, and making informed decisions—whether through self-directed actions or by seeking assistance [8]. Awareness of type 2 diabetes management and hypoglycemia symptoms has been shown to positively influence patients' ability to detect hypoglycemia [9]. Independent blood glucose monitoring can be successfully implemented after appropriate training [10]. Enhanced knowledge of type 2 diabetes management and hypoglycemia symptoms contributes significantly to improving patients' self-awareness and response to hypoglycemic events [11].

Knowledge, as a product of the learning process, is a dynamic element capable of shaping an individual's actions [12]. The Health Belief Model (HBM) serves as a theoretical framework for analyzing health-related behaviors and the factors influencing a person's compliance with health management guidelines [13, 14]. According to the HBM, people are more inclined to adopt health-enhancing practices when they acknowledge their susceptibility to potential health risks (Perceived Susceptibility), comprehend the gravity of those risks (Perceived Severity), believe in the positive outcomes of adopting healthier behaviors (Perceived Benefits), and can effectively overcome challenges to implementing those behaviors (Perceived Barriers) [15, 16].

Moreover, self-efficacy (the confidence in one's capacity to carry out particular tasks) serves as a pivotal factor in fostering positive health behaviors and eliminating harmful ones. Cues to action represent the stimuli or signals that encourage individuals to initiate behavior change [17, 18]. A study conducted by Shabibi *et al.* on the effectiveness of HBM-based educational interventions in promoting self-care practices among patients with type 2 diabetes mellitus (T2DM) revealed notable enhancements in perceived susceptibility, severity, benefits, barriers, self-efficacy, and self-care behaviors, all of which were statistically significant ($p<0.001$) [19].

Advancements in science and technology continue to drive efforts to integrate technology into the learning process. The adoption of new technologies enhances the role of specialized nurses by enabling the efficient and sustainable implementation of technology-based nursing practices [20]. This involves identifying and utilizing technology and application systems that align with the care plans and specific needs of patients with diabetes mellitus [21].

According to Mayer, multimedia refers to the presentation of material using a combination of text and images, which facilitates better comprehension among learners compared to text-only formats [22]. The cognitive theory of multimedia posits that humans process information through two channels (visual and auditory) each with limited capacity. An active learning process engages these cognitive channels, promoting coordination and improving the understanding of educational material [23, 24].

The integration of mobile health technology into diabetes mellitus education represents an innovative approach to engaging patients and promoting positive health behaviors. Various mobile technology-based strategies have been employed to assess their effectiveness, including videophones, mobile phones tailored for diabetes management [25-27], mHealth management applications aimed at improving adherence and preventing hypoglycemia [28, 29], and smartphone applications such as Hypomap, designed to reduce hypoglycemia in type 1 diabetes mellitus. Additionally, the IMB-DSC model has been used to evaluate self-care behaviors [30].

Despite these advancements, there is a notable lack of research on the development of diabetes education models utilizing smartphone applications specifically designed to prevent and detect hypoglycemia in patients with type 2 diabetes mellitus. A systematic review conducted by Mufidah *et al.* [31] highlights the potential benefits of smartphone applications as educational tools for individuals with diabetes mellitus, emphasizing their value as a medium for patient education.

In 2023, we designed a health education framework rooted in the principles of the Health Belief Model to aid in the prevention of hypoglycemia among individuals with diabetes mellitus. The model was designed and developed using the ADDIE framework, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. This educational model represents a scientifically grounded learning design, detailed in an academic paper. To assess its practicality and effectiveness, researchers created a website-based prototype as part of the model's development—a smartphone application named NEDTA (Nursing Education Diabetic Therapeutic Application). Field trials are essential to validate the application's capability to accurately detect early signs of hypoglycemia. Building on this foundation, the researchers aim to study the impact of this Health Belief Model-based education on patients' ability to prevent hypoglycemia in diabetes mellitus.

Materials and Methods

Study design

The research employs a design and development methodology, utilizing the ADDIE framework as the guiding model. The process follows a structured sequence of phases: Analyze, Design & Development, Formative Evaluation, and Evaluation [32].

Respondent

The study took place between February and August 2024 in the service areas of Puskesmas Simpang Kawat and Puskesmas Pakuan Baru. Primary data were gathered via interviews, utilizing questionnaires administered to 36 participants in the intervention group and 36 in the control group. The sample size was determined using the methodology proposed by Sastroasmoro & Ismael [33]:

$$n=\frac{[(Z_{\alpha}+Z_{\beta}).Sd)]^{2}}{d^{2}}$$

The sample size was determined using a formula incorporating a 5% Types I error rate ($Z\alpha=1.96$) and a 10% Type II error rate ($Z\beta=1.28$). Mean values for the pre- and post-intervention groups were referenced from prior work by Song *et al.* [34], with a pre-intervention average of 9.52, a post-intervention average of 12.11, and a standard deviation of 4.46. Based on these inputs, the calculated sample size (n) was 31.128, which was rounded up to 32 participants. To mitigate the impact of potential dropouts, an additional 10% (4 participants) was included, leading to a final count of 36 respondents per group for both intervention and control. Eligibility criteria required participants to own and be proficient in using a smartphone, demonstrate willingness to cooperate, and provide informed consent for participation.

Variables and instrument

The primary outcome of this study is the capacity to prevent hypoglycemia. Data were gathered through a questionnaire aimed at evaluating the cognitive skills of individuals with diabetes mellitus in managing hypoglycemia prevention. The instrument was adapted from a validated and reliable tool developed by Supadi [35] and underwent thorough validity and reliability testing. Validity assessments demonstrated that all items had correlation coefficients exceeding the threshold value (r table), confirming their validity. Reliability analysis produced a Cronbach's Alpha score of 0.85, signifying that the questionnaire is highly reliable.

The questionnaire included 20 items, with a score of 1 given for correct responses and 0 for incorrect ones. The scores reflecting the ability to prevent hypoglycemic episodes were treated as ratio data, with a possible range from 0 to 20. These assessments were carried out through both pre-test and post-test evaluations.

The Health Belief Model (HBM) Health Education Model, a design product based on the following phases: Analyze, Design & Development, Formative Evaluation, and Evaluation. This smartphone-based HBM health education model was implemented to prevent hypoglycemia in patients with diabetes mellitus.

Data collection

The data collection process began with discussions with the development team to revise the existing application by adding images and explanations to the media. The application was then validated by IT experts to ensure that the website-based educational tool was suitable for use in the research [36]. Next, respondents were identified according to the inclusion criteria: 36 diabetes mellitus (DM) patients from the Simpang Kawat Puskesmas work area (intervention group) and 36 DM patients from the Pakuan Baru work area (control group). Informed consent was obtained from all participants.

In the intervention group, a socialization session was conducted to explain the application and its usage on smartphones. Participants were provided with an application manual and video tutorials to ensure they could use the application independently, without the need for researcher assistance. The hypoglycemia prevention application was then installed on the respondents' smartphones.

Participants were instructed to complete the pre-test items via the application. The intervention, which was grounded in the Health Belief Model (HBM) Health Education Framework, took place over two months, providing participants with sufficient time to explore, engage with, and internalize the information offered in the hypoglycemia prevention application. After two months, a post-test evaluation was conducted. In the control group, a socialization session was held to provide an explanation of diabetes mellitus (DM) and hypoglycemia, along with the distribution of a pocketbook on hypoglycemia and its management. A pre-test was then conducted. Respondents were asked to review and familiarize themselves with the material in the pocketbook. After two months, a post-test evaluation was conducted. Throughout the research activities, the researchers were supported by six enumerators who had been trained for the study.

Data analysis

Descriptive statistics, including mean, standard deviation (SD), minimum, and maximum values, were used to analyze the univariate data for age and duration of diabetes mellitus (DM). For categorical data such as gender, education level, occupation, history of hypoglycemia, glucometer ownership, and type of DM medication, frequency distributions were calculated.

The distribution of the data was first evaluated using the Kolmogorov-Smirnov test, which confirmed that the data followed a normal distribution. Following this, inferential statistical analysis, including dependent and independent t-tests, were conducted to compare mean values and assess the mean differences between the two groups.

All tests were performed with a significance level set at $p<0.05$, and data analysis was carried out using SPSS version 23.0.

Ethical consideration

Ethical approval for this study was granted by the Health Research Ethics Commission of the Health Polytechnic of the Ministry of Health in Jambi, under approval number: LB.02.06/2/300.1/2024.

Findings

Table 1. Distribution of demographic and clinical characteristics of diabetes mellitus patients

Characteristic	Intervention n (%)	Control n (%)
Age		
Mean±SD	59.920±8.804	62.890±7.622
Gender		
Male	12 (33.3)	13 (36.1)
Female	24 (66.7)	23 (63.9)
Education		
Not schooling	1 (2.8)	2 (5.6)
Elementary	1 (2.8)	11 (30.6)
Junior school	1 (2.8)	9 (25.0)
High school	26 (72.2)	10 (27.8)
College	7 (19.4)	4 (11.1)
Occupation		
Civil servant	3 (8.3)	1 (2.8)
Labor	2 (5.6)	7 (19.4)
Retirement	10 (27.8)	2 (5.6)
Entrepreneur	0 (0)	4 (11.1)
Private sector	0 (0)	1 (2.8)
Housewife	21 (58.3)	21 (58.3)
History of hypoglicemia		
None	72.2)	20 (55.6)

Ever	10 (27.8)	16 (44.4)
Glucometer possession		
Yes	16 (44.4)	21 (58.3)
No	20 (56.6)	15 (41.7)
Use of DM medications		
Oral medication	30 (83.3)	33 (91.7)
Insulin injection	6 (16.7)	3 (8.3)
Duration of DM		
Mean±SD	5.220±5.205	4.000±2.042

Table 1 the demographic and clinical characteristics of the study participants. The intervention group was younger (59.92 years) compared to the control group (62.89 years), with the majority being female. Most participants in the intervention group had a high school education, while the control group was dominated by elementary school graduates. The most common occupation in both groups was housewife. Most of the intervention group had no history of hypoglycemia, while glucometers were more commonly owned by the control group. The primary treatment in both groups was oral medication, with the average duration of diabetes slightly longer in the intervention group.
An improvement in hypoglycemia prevention scores in both the intervention and control groups. In the intervention group, the average pre-test score was 48.110±6.173, with a median of 47, which rose to 55.890±6.923, with a median of 58, in the post-test. This change was statistically significant, with a p-value of 0.0001. For the control group, the mean pre-test score was 43.170±4.748, with a median of 44, which increased to 45.390±5.929, with a median of 45, in the post-test. This increase was also found to be statistically significant, with a p-value of 0.0001.
A noteworthy difference in hypoglycemia prevention abilities between the intervention and control groups in the post-test. The intervention group had a mean score of 50.640±6.426 for hypoglycemia prevention. Statistical analysis confirmed the significance of this difference, with a p-value of 0.0001, indicating that the intervention effectively contributed to a greater improvement in hypoglycemia prevention compared to the control group.

Discussion

The data showed that more than two-thirds of the participants were women. Global studies generally indicate that women are at a higher risk of hypoglycemia than men. Yang *et al.* [37] found a significant correlation between gender and hypoglycemia (p-value=0.001), with women experiencing more frequent hypoglycemic episodes. This could be linked to hormonal changes during menopause, such as reduced estrogen and progesterone levels, which may lead to increased fat storage and alterations in lipid profiles, ultimately decreasing insulin sensitivity in the liver and muscles [38, 39]. While some research suggests no significant difference between men and women in detecting hypoglycemic events [40], overall, women tend to be more vulnerable to hypoglycemia.
The majority of participants in the intervention group had a high school education, which likely made it easier for them to understand the information provided by the researchers. Education level is an important factor in knowledge improvement, as individuals with higher education are generally assumed to absorb information more easily. However, education level should not be seen as an indicator of mastery in specific fields but rather as a sign that an individual has completed formal education in a particular area. The ability to prevent hypoglycemia results from the interaction of knowledge, attitudes, and actions regarding hypoglycemia management, which can be gained through personal experiences, others' experiences, media, or formal education. According to Chrisanto & Agustama [40], education level influences an individual's ability to understand their health condition. Those with lower education levels may struggle to recognize health issues and understand disease management guidelines, whereas individuals with higher education levels are better equipped to recognize health-related factors and understand the long-term implications for their health.
The participants in the intervention group were, on average, in the elderly age range. This suggests that the individuals had considerable life experience and well-developed decision-making and judgment abilities. However, older adults are more vulnerable to hypoglycemia due to factors such as diminished kidney function, which impairs drug clearance, the use of multiple medications and potential drug interactions, and a decline in cognitive abilities [41]. Cognitive decline in older adults can increase their risk of hypoglycemia, while hypoglycemic episodes can also worsen or contribute to further cognitive impairments [42].

The duration of Diabetes Mellitus (DM) is often directly related to the improvement in experience, particularly for family members living with individuals who have DM. Based on the study results, the average duration of diabetes in the intervention group was a bit more than five years. For patients themselves, a longer duration of DM increases the likelihood of experiencing hypoglycemia. Over time, individuals with DM tend to have more frequent hypoglycemic episodes, making these experiences a key stimulus for preventing hypoglycemia. The theory of pain behavior suggests that individuals who frequently experience pain or its symptoms are more likely to be attentive to their condition and seek appropriate help [28].

The Health Belief Model (HBM) health education approach aims to strengthen the ability of individuals with Diabetes Mellitus (DM) to prevent hypoglycemia. This model is built on the Health Belief Model theory, which provides a framework for understanding the factors that drive health behaviors and influence whether people follow or ignore health management guidelines. According to the HBM, individuals are more inclined to adopt health-promoting actions if they believe they are at risk (Perceived Susceptibility), acknowledge the seriousness of the risk (Perceived Severity), trust that making changes will yield positive outcomes (Perceived Benefit), and feel confident in overcoming obstacles to adopting healthier behaviors (Perceived Barriers). Additionally, self-efficacy refers to the individual's confidence in their ability to take action, improve health, and eliminate harmful habits. Cues to action are the signals or motivations that prompt individuals to initiate change [16]. Research by Shabibi *et al.* [19] found that using HBM-based educational interventions significantly improved self-care behaviors in individuals with type 2 diabetes (T2DM), showing improvements in perceptions of risk, severity, benefits, barriers, self-efficacy, and overall attitudes toward health management [19, 43, 44].

The NEDTA application is designed to provide individuals with Diabetes Mellitus (DM) the opportunity to learn at their convenience, anytime and anywhere. At the start of the study, not all participants were able to access the application link provided by the researchers. However, the initial socialization meeting helped facilitate the process by allowing the researchers and their team to assist participants in installing the application on their smartphones. The researchers recognized that effectively utilizing mobile applications for health promotion requires clear communication and commitment-building, ensuring that participants engage fully with each activity. Simply sharing the application link does not guarantee active participation in efforts to maintain health. Therefore, a comprehensive strategy is essential to ensure the effectiveness of smartphone-based education for adults. This includes identifying the participants' informational needs, defining performance objectives, developing appropriate steps for transferring information through the smartphone, and ultimately evaluating the impact of the intervention on improving the ability of DM patients to detect hypoglycemia.

The intervention aimed at improving the competence of Diabetes Mellitus patients focuses on providing education about the disease process, treatment, and prevention of hypoglycemia complications. Education is delivered through health promotion, which empowers individuals and communities to maintain and enhance their health. This empowerment goes beyond simply sharing information (such as health education) and includes efforts to change behaviors and attitudes. The involvement of community cadres and Puskesmas in this educational program is crucial, as it enables the community to play an active role in managing Diabetes Mellitus and improving self-care behaviors among patients. This approach aligns with Indonesian government policy, particularly in the context of the infectious disease prevention and control program.

Conclusion

The implementation of a health education model based on the Health Belief Model was effective in enhancing the ability of Diabetes Mellitus patients to prevent hypoglycemia. The intervention demonstrated a significant impact compared to the non-intervention group, indicating that a structured educational approach can help patients better understand and manage the risks associated with hypoglycemia.