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Social Support, eHealth Literacy, and mHealth Use in Older Adults With Diabetes

Moderated Mediating Effect of the Perceived Importance of App Design

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Mobile healthcare has emerged as a prominent technological solution for self-management of health. However, the development and utilization of tailored mobile healthcare applications for older adults with diabetes mellitus remain limited. This study examined the relationship between social support and mobile healthcare use and further explored how this relationship varies with eHealth literacy and application design among older adults with diabetes mellitus. A descriptive cross-sectional trial was conducted with a structured self-report questionnaire, surveying 252 South Korean older adults with diabetes mellitus via offline and online modes. The mediating effect and moderated mediating effect were analyzed with the PROCESS macro of SPSS. eHealth literacy mediated the relationship between social support and mobile healthcare use. High levels of eHealth literacy and social support may increase mobile healthcare use among older adults with diabetes. Application design aesthetics facilitated mobile healthcare use. Future researchers, healthcare providers, and developers can contribute to the development of tailored mobile healthcare applications for older adults with diabetes mellitus by considering application design aspects such as font size, color, and menu configuration.

KEY WORDS: Diabetes mellitus, mHealth use, Moderated mediating effect, Older adults

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Diabetes mellitus is a chronic disease with rapidly increasing global prevalence and mortality rates. [1,2] It requires long-term care, and the possibility of complications and mortality increases with age; therefore, diabetes self-management is important, especially for older adults.[2] Mobile healthcare (mHealth) is a new technological paradigm of self-management of health that allows users to directly manage their health records and status and collect information on health.[3–5] Previous studies have revealed that the mHealth use improves self-management and diabetes outcomes.[6–8]

An aging population and the increasing prevalence of chronic diseases have led to growing interest and demand for mHealth.[5,9,10] While Internet usage among older adults is increasing,[11] there are physical, psychological, and environmental barriers hindering the use of mHealth applications (apps) among these potential consumers of these technologies.[12,13]

In previous studies, social support and eHealth literacy have been found to influence the adoption and utilization of mHealth among older adults. Social support has been shown to have a positive impact on healthcare behavior and the use of health-related technology among older adults.[14–16] Notably, support from family, friends, and healthcare providers has been found to enhance self-care behavior in this population.[16] In addition, social support has been positively associated with eHealth literacy, [17] as it provides older adults with access to information, resources, and encouragement, thereby motivating their engagement with the Internet and mHealth use.[18–21]

Grounded in health literacy, eHealth literacy refers to the essential skills needed to utilize technology and ability to seek, find, and understand health information from electronic sources.[18,19] Previous research has found that eHealth literacy is associated with health behaviors. Specifically, higher levels of eHealth literacy were found to positively influence self-care for diabetes, Internet use, and mHealth app use.[22,23] Conversely, lower eHealth literacy has been associated with poor diabetes self-management and poor health outcomes among older adults with diabetes mellitus.[24,25] The level of eHealth literacy is influenced by various factors. The digital divide, sociodemographic characteristics including older age, lower education levels, limited health literacy, and inadequate social support have been associated with lower eHealth literacy.[26] In addition, psychological factors such as confidence and

self-efficacy in using technology have been found to significantly impact eHealth literacy.[17,23,24]

In a recent study, eHealth literacy was studied as a mediator of health behavior in chronic illness.[21] Similarly, eHealth literacy can also serve as a mediating factor between social support and mHealth use, thereby expanding the availability of social support. However, limited published data exist on whether social support influences mHealth use through eHealth literacy among older adults with diabetes mellitus.

Application design issues, such as difficulty of navigation, small button sizes, and inadequate data visualizations, may affect usability of mHealth for older adults.[9,27] Studies have shown that age-related declines in cognition, perception, physical abilities, and motivation may also contribute to reduced mHealth use among older adults.[28–30] To address these challenges, previous research has provided design guidelines including larger font sizes, contrasting colors, and clear navigation menus, as well as modifying the level of app functionality to facilitate mHealth use for older users.[27,30] Designing mHealth specifically tailored to the needs of older adults with diabetes mellitus may enhance the relationship between eHealth literacy and mHealth use. However, because of limited research data, further exploration is needed to better understand the impact of design on the use of mHealth.

Overall, these prior studies indicate that social support, eHealth literacy, and app designs tailored to the specific needs of older adults play significant roles in influencing their use of mHealth. However, the relationship between social support and mHealth use among older adults with diabetes may be more complex than previously suggested. Accordingly, our study investigated the mediating effect of eHealth literacy and the moderating effect of perceived importance of app design on the relationship between social support and mHealth use among older adults with diabetes mellitus.

Building upon the existing literature, we developed a conceptual framework in which eHealth literacy mediated the relationship between social support and mHealth use, with the mediation effects differing among individuals who scored high versus low on perceived importance of app design. Specifically, we hypothesized that perceived importance of app design would moderate the second stage of the mediation process (Figure 1).

The study was conducted in two steps: investigating whether (1) social support affects mHealth use through eHealth literacy (a mediation model) and (2) the strength of the mediated effect through eHealth literacy varies with differing levels of app designs' perceived importance (a moderated mediation model).

The findings of this study could inform the development of future interventions aimed at promoting mHealth use among older adults and may serve as a reference for designers and developers in creating mHealth apps that are tailored to the specific needs of older adults.

RESEARCH DESIGN AND METHODS

Study Design, Participants, and Procedures

Study Design

This descriptive, cross-sectional study of older adults with diabetes was conducted via a structured self-report questionnaire. Data were collected through convenience sampling.

Participants and Data Collection

The inclusion criteria were participants who (1) were 65 years or older; (2) had diabetes for at least 6 months; (3) were residents of South Korea; (4) consented to participate in the research; (5) were without physical discomfort that rendered them unable to respond; (6) had basic literacy skills; and (7) had the cognitive ability to respond to the self-report questionnaires. Based on G*Power 3.1.9.7 software (Heinrich Heine University, Dusseldorf, Germany), the required sample size was determined to be 234 participants. Cohen's *D* effect size was set to 0.15 (moderate) based on Cohen's criteria and previous literature on older adults with diabetes[31,32]; α type I error was .05, power was 0.95, and the number of predictors was 23.[33]

The survey was administered via online and offline mixed-modes perspectives.[34–36] Paid advertisements were used for the online survey through the "Invight" online panel aggregator, from December 10, 2021, to December 19, 2021. Participants recruited via this panel received a text message inviting them

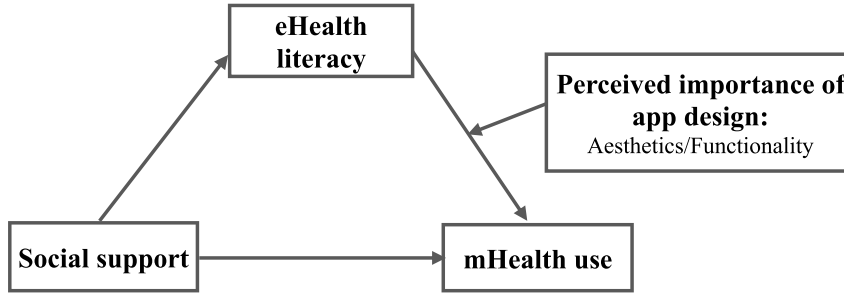

FIGURE 1. Conceptual model.

to participate by clicking on a link that directed them to a screening questionnaire to assess eligibility. A total of 180 participants took the online survey, but 47 were excluded for invalid data entry. The offline survey was conducted at two clinics in urban South Korea between December 20, 2021, and January 20, 2022. The participants were recruited through flyers placed in the outpatient units of these clinics. Prior to the survey, physicians screened potential participants and selected those who met the inclusion criteria.

Measures

Demographic and Health Information

The participants provided demographic and health information such as age, sex, glycated hemoglobin (HbA_{1c}), diabetes type, diabetes self-management knowledge, and self-rated health. To measure diabetes self-management knowledge, the Diabetes Self-Management Knowledge Scale for Older Adults[37] was used. It consists of 22 questions; incorrect answers were coded as 0 and correct answers as 1. Self-rated health was measured on a 5-point Likert-type scale, ranging from 1 (poor health) to 5 (excellent health). In addition, participants disclosed the duration of having diabetes.

Social Support

The Multidimensional Scale of Perceived Social Support developed by Zimet et al[38] was used to measure the support received from family, friends, and other meaningful relationships. It comprises 12 questions, which are rated on a 5-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The total score ranges from 12 to 60; higher scores indicate greater social support. A previous study reported a Cronbach's α value of .85.[38] The Cronbach's α value in this study was .924.

eHealth Literacy

eHealth literacy is the ability to find, understand, evaluate, and apply online health information to meet healthcare needs.[19] This study used the Korean version of the eHealth Literacy Scale,[39] which is based on the eHealth Literacy Scale originally developed by Norman and Skinner,[19] to measure the level of eHealth literacy. The scale comprises 10 questions, each of which is rated on a 5-point Likert scale, which ranges from 1 ("strongly disagree") to 5 ("strongly agree"). The score did not include the first two questions on the usefulness and importance of the Internet in the health-related decision-making process. The total score ranges from 8 to 40. Higher scores indicate greater eHealth literacy. A previous study reported a Cronbach's α coefficient of .88,[39] and the Cronbach's α in this study was .973.

Perceived Importance of App Design

The perceived importance of app design was measured by two constructs: aesthetics and functionality.[40] There were 12 questions, three of which addressed aesthetics (font size, color, and menu configuration), and three of which assessed functionality (connectivity between exercise machines and blood glucose meter, and voice recognition). The additional six questions corresponded to the participant's motivation to use the mHealth app with these aesthetics and functionality. All items were rated on a 5-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The score was calculated by multiplying the answers to the six questions on the perceived importance of app design and motivation. The total score range for aesthetics and function was 6 to 30; higher scores indicated greater perceived importance of app design in the use of mHealth. In this study, Cronbach's α values for aesthetics and function were .873 and .866, respectively.

Mobile Health Use

This study defined mHealth use as the "intention to continuously and regularly use diabetes self-management applications."[41] The measured items consisted of three statements, such as "I intend to use a diabetes self-management application," which were rated from 1 ("strongly disagree") to 5 ("strongly agree"). The range of the total score was from 3 to 15; higher scores indicated a greater intention to use the app. Hoque and Sorwar[42] and Almegbel and Aloud[43] investigated the intention to use mHealth; Cronbach's α values were reported to be .936 and .927, respectively. In this study, the Cronbach's α value was .958.

Ethical Considerations

This study was approved by the Research Ethics Committee of a university (7001988-202206-HR-1387-04). Participation was completely voluntary, and the participants could withdraw from the study at any stage. Detailed instructions on the method of responding to the questionnaire and an explanation about the nature of the study were provided to the participants prior to administering the questionnaire. Written consent was obtained from the participants. It was clearly specified that no identifiable personal information would be collected. A reward of US $2.50 and $10.00 was given to the online and offline survey participants (those who completed the survey with valid answers), respectively. The difference in compensation for online and offline survey participants was based on time and convenience perspectives.

Statistical Analysis

Data analyses were performed using SPSS version 25.0 (IBM, Armonk, NY, USA) and the PROCESS macros (version 4.0) within SPSS.[35,44] Descriptive statistics (means, SDs, and proportions) were used to describe demographic and health information. Independent *t* tests and analysis of variance were used to identify differences in mHealth use by demographic and health information and main variables. The strength of relationships between all of the variables included in the model

was verified using Pearson's correlations prior to model construction. The key research questions were assessed using moderated mediation regression analyses, following Hayes'[44] recommendations, with the PROCESS macro of SPSS.[35,44] First, the PROCESS macro-Model 4 was used to examine the mediating effect of eHealth literacy on the relationship between social support and mHealth use. After the simple mediation model was confirmed, the moderated mediation model was constructed using the PROCESS macro-Model 14. It examined whether the perceived importance of app design moderated the relationships between eHealth literacy, social support, and mHealth use. Subsequently, to explore the mechanism of influence between the perceived importance of app design and eHealth literacy, we conducted a simple slope analysis with focal points at the mean, 1 SD above and below the mean, as recommended by Cohen.[33] We applied the Johnson-Neyman technique to demonstrate a more detailed range of control effects.

We used only two-sided tests, with $P < .05$ indicating statistical significance, and bias-corrected bootstrapped confidence intervals to assess the statistical significance of the indirect mediation effects. Missing values for two items were reported and excluded from the analysis.

RESULTS

Descriptive Analysis

Among the 252 valid responses, 119 were from the offline and 133 from the online recruitment and surveys (Supplementary Table 1, Supplemental Digital Content 1, http://links.lww.com/CIN/A310). The average age was 72.13 (SD, 5.28) years; all demographic and health characteristics, with the exception of the duration of diabetes, were associated with significant differences in mHealth use (Table 1).

Correlation Analysis

The correlations between the main variables for all participants are presented in Supplementary Table 2, http://links.lww.com/CIN/A310. Mobile healthcare use had significantly positive correlations with all four main variables ($P < .001$).

Mediating Effect

The results indicated that eHealth literacy partially mediated the relationship between social support and mHealth use among older adults with diabetes. Bootstrapping results with 5000 samples showed that the mediation effect had a statistically significant complementary relationship (direct effect = 0.218; 95% confidence interval [CI], 0.044–0.392;

Table 1. mHealth Use Based on Demographic and Health Characteristics and Main Variables (N = 252)

Characteristics	Variables	n (%) or Mean (SD)	mHealth Use	
			Mean (SD)	*t* or *F* (*P*)
Demographic information	Age, y	72.13 (5.28)		2.84 (<.001)
	65–74	179 (71.0)	3.73 (0.83)	13.54 (<.001)
	75–84	66 (26.2)	3.17 (0.97)	
	≥85	7 (2.8)	2.67 (0.96)	
	Sex			
	Men	177 (70.2)	3.66 (0.91)	2.89 (.004)
	Women	75 (29.8)	3.30 (0.91)	
	Diabetes self-management knowledge	16.88 (3.07)		2.68 (.001)
Health information	Type of diabetes			
	Type 1	49 (19.4)	3.89 (0.67)	3.61 (<.001)
	Type 2	203 (80.6)	3.47 (0.95)	
	Duration of diabetes, y	13.48 (10.16)		0.70 (.900)
	Missing	6 (2.4)		
	HbA_{1c}	7.15 (1.49)		
	≤7.0	152 (60.3)	3.66 (0.90)	1.97 (.049)
	>7.0	88 (34.9)	3.42 (0.94)	
	Missing	12 (4.8)		
	Self-rated health	2.88 (0.81)	—	2.68 (.001)
Main variables	mHealth use	3.55 (0.92)	—	—
	Social support	3.47 (0.64)		1.80 (.006)
	eHealth literacy	2.93 (1.01)		3.02 (<.001)
	Perceived importance of app design			
	Aesthetics	3.85 (0.65)		3.71 (<.001)
	Functionality	3.52 (0.75)		7.84 (<.001)

Range of the main variables (social support, eHealth literacy, mHealth use, and perceived importance of app aesthetics and functionality) = 1–5.

indirect effect = 0.229; 95% CI, 0.139–0.334; total effect = 0.447; 95% CI, 0.277–0.616; Table 2).

Moderated Mediating Effect

The results confirmed that the mediating effect of eHealth literacy on the relationship of social support and mHealth use conditionally varied, depending on the level of perceived importance of app aesthetics. Bootstrapping results with 5000 samples revealed that the moderated mediating effect of app aesthetics' perceived importance was statistically significant (index of moderated mediation = 0.115; 95% CI, 0.011–0.222). However, perceived importance of app functionality did not have a moderated mediating effect (index of moderated mediation = 0.025; 95% CI, −0.064–0.111; Table 3; Supplementary Figure 1, http://links.lww.com/CIN/A309).

In the slope analysis, the simple regression line demonstrated a significant difference between low and high perceived importance of app aesthetics in the results of the moderation effect analysis. Specifically, in the group with the high perceived importance of app aesthetics, eHealth literacy had a greater effect on mHealth use (Supplementary Figure 2, http://links.lww.com/CIN/A309). Application of the Johnson-Neyman technique revealed that the perceived importance of app aesthetics was significantly associated with mHealth use when the value was −0.651 or higher (Supplementary Figure 3, http://links.lww.com/CIN/A309).

DISCUSSION

Our study investigated the mediating role of eHealth literacy in the relationship between social support and mHealth use, as well as the moderating effect of perceived importance of app design on the relationship between eHealth literacy and mHealth use among older adults with diabetes mellitus. We demonstrated mHealth use for diabetes self-management and clarified under what conditions the mediation effect varied according to different personal characteristics.

The results of this study revealed that intention to use mHealth was associated with demographic factors, such as age and sex, as well as health characteristics, including better self-rated health and well-controlled HbA_{1c} levels. These findings are consistent with previous research, which has shown that younger age, male sex, and good physical functioning ability are associated with a higher prevalence of technology use in older adults with diabetes.[13] In addition, our study found that individuals with type 1 diabetes had a greater intention to use mHealth compared with those with type 2 diabetes. This could be because individuals with type 1 diabetes are more familiar with the use of technology because of their frequent need for glucometer implementation and continuous monitoring in their daily routine. Moreover, they often utilize insulin administration devices such as insulin pens or pumps.[45]

Our findings revealed a direct and positive association between social support and mHealth use among older adults with diabetes. These results are consistent with previous studies that highlighted the influence of social support on the utilization of digital devices.[14–16] The findings suggest that the social support provided by family, friends, neighbors, and peer groups is crucial in encouraging the adoption and use of mHealth technologies among older adults with diabetes. These social support networks play an important role in promoting engagement with mHealth tools and resources, ultimately enhancing self-management and health outcomes.[14,16,25,46]

Our study found that social support not only directly influenced mHealth use but also had an indirect influence by acting as a mediator of eHealth literacy. The results demonstrated that positive social support had a stronger effect on increasing mHealth use among older adults with diabetes when combined with higher levels of eHealth literacy. This

Table 2. Mediating Effect of eHealth Literacy on the Relationship Between Social Support and mHealth Use (N = 252)

Direct Effect	*B*	SE	*t*	*P*	95% CI	
					LLCI	ULCI
Social support (X) → eHealth literacy (M)	0.656	0.090	7.309	<.001	0.479	0.833
R^2 = 0.176, *F* = 53.281 (*P* < .001)						
Social support (X) → mHealth use (Y)	0.218	0.088	2.465	.014	0.044	0.392
eHealth literacy (M) → mHealth use (Y)	0.348	0.057	6.156	<.001	0.237	0.460
R^2 = 0.216, *F* = 34.389 (*P* < .001)						
Indirect Effect	**Effect**		**Boot SE**		**95% CI**	
					Boot LLCI	**Boot ULCI**
(X → M → Y)	0.229		0.050		0.139	0.334
R^2 = 0.097, *F* = 26.962 (*P* < .001)						

Abbreviations: *B*, estimate of the regression coefficient; *F*, *F* test value; LLCI, low-limit confidence interval; R^2, explanatory power; SE, standard error of estimate; ULCI, upper-limit confidence interval.

Table 3. Moderated Mediating Effect of Importance of App Aesthetics and Functionality (N = 252)

Variables	mHealth Use (Y)				95% CI	
	B	SE	*t*	*P*	LLCI	ULCI
Social support (X)	0.190	0.083	2.291	.023	0.027	0.354
eHealth literacy (M)	0.278	0.054	5.133	<.001	0.171	0.385
Perceived importance of app aesthetics (W1)	0.469	0.079	5.935	<.001	0.313	0.624
eHealth literacy × perceived importance of app aesthetics (M × W1)	0.176	0.069	2.536	.012	0.039	0.313
Social support (X)	0.087	0.079	1.103	.270	−0.070	0.242
eHealth literacy (M)	0.181	0.053	3.437	.001	0.077	0.285
Perceived importance of app functionality (W2)	0.617	0.069	8.939	<.001	0.481	0.752
eHealth literacy × perceived importance of app functionality (M × W2)	0.038	0.055	0.688	.492	−0.071	0.147

Index of moderated mediation, aesthetics = 0.115 (95% bootstrap CI, 0.011–0.222); functionality = 0.025 (95% bootstrap CI, −0.064 to 0.111).

Abbreviations: *B*, estimate of the regression coefficient; LLCI, low-limit confidence interval; M, mediator; *P*, significance probability; ULCI, upper-limit confidence interval; W, moderator; *X*, independent variable; *Y*, dependent variable.

finding is consistent with previous research emphasizing the promotion of self-management services through enhanced eHealth literacy.[21,23,24,47] Higher eHealth literacy levels in older adults contribute to increased motivation to use technology, facilitating their engagement with mHealth interventions.[14,18,19,21] Therefore, our study suggests that social support acts as an antecedent variable, facilitating the utilization of mHealth technologies among older adults through the mediating pathway of eHealth literacy.

Furthermore, our main finding demonstrated a significant interaction between perceived importance of app design (eg, aesthetics) and eHealth literacy, which had a significant effect on mHealth use. Further analysis revealed that among those who had higher perceived importance of app aesthetics, eHealth literacy had a stronger effect on mHealth use. This highlights the role of app design aesthetics as a facilitator of eHealth literacy, mediating the relationship between social support and mHealth use. These findings are consistent with previous studies that found design plays an essential role in the acceptance of new technologies[48] and design aspects including screen/display size, color, material, menu structure, user-friendliness, and accessibility, and simplified operations can also significantly influence mHealth adoption and use, particularly among older adults.[9,49] Therefore, when designing interventions or applications targeting older adults with diabetes, healthcare providers or app developers should focus on aesthetic features that consider the physical, sensory, and cognitive changes experienced by older adults, such as impaired vision, slow hand movement, and decreased response time.[27,28,50]

In contrast, the functional features of app design, such as connectivity between exercise machines and blood glucose meter, as well as voice recognition, received lower ratings in comparison to design aesthetics and did not exhibit a significant moderating effect. These discrepancies can be partially attributed to the fact that previous studies involved older adults with lower levels of digital engagement.[13] However, it is worth noting that the participants in our study had an average age of 72.13 years, which is older than the typical baby boomer or emerging older adult population. Older adults often face greater challenges and stress when learning new information and technologies.[51] Consequently, the specific app features may have been unfamiliar to the participants and perceived as less important or unfamiliar, leading to a weaker association with eHealth literacy and mHealth use.

Limitations

This study has some limitations. First, this is a cross-sectional study; hence, causal relationships for the tested model could not be inferred. Second, only self-reported data were used, which can introduce common method and possible social desirability biases. Therefore, additional experimental or longitudinal studies should be performed to test the actual direction of the relationship using panel data containing long-term observations.

Furthermore, we used a mixed- mode of data collection (online and offline) to reduce potential sample bias caused by a single mode.[34–36] However, selection bias, such as younger participants, geographically distant older adults, and men, may have occurred. Future research should compare the results depending on participating channels, including individual differences (eg, digital literacy, individual commitment to self-manage, or mHealth user experience).

CONCLUSION

Although numerous applications for self-management of diabetes have been developed globally, their development and utilization for older adults are still in the early stages. In this study, we found that social support influenced mHealth use through the mediating role of eHealth literacy. Application design aesthetics was a facilitating factor that promoted mHealth use. This study identified the conditions under which

the mediation effect between social support and mHealth use varied according to eHealth literacy levels. Specifically, our findings suggest that app design should be considered to enhance the use of mHealth among older adults with a high eHealth literacy. Developers should consider the specific needs related to app design, such as font size, color, and menu configuration. This is particularly important due to the physical, sensory, and cognitive changes that occur with aging. By addressing these factors, future researchers, healthcare providers, and developers can contribute to the development of tailored mHealth applications for older adults with diabetes mellitus.

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