Determinants of Digital Health Technology Acceptance Among Healthcare Caregivers: A Structural Equation Modeling Approach

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Abstract

Background: Digital health technologies, including artificial intelligence (AI)-powered tools and virtual reality (VR) interventions, are increasingly being deployed to support caregivers of patients with chronic conditions. However, the factors influencing caregiver acceptance of these technologies remain poorly understood.

Objective: This study aimed to develop and validate a structural equation model (SEM) to examine the determinants of digital health technology acceptance among caregivers of patients with end-stage kidney disease (ESKD).

Methods: A cross-sectional survey was conducted among 342 caregivers recruited from nephrology clinics across three tertiary hospitals in Singapore. The survey instrument measured perceived usefulness, perceived ease of use, social influence, facilitating conditions, caregiver burden, technology anxiety, and behavioral intention to use digital health tools. Confirmatory factor analysis (CFA) and structural equation modeling were performed using maximum likelihood estimation.

Results: The final SEM demonstrated good model fit (CFI = 0.952, TLI = 0.943, RMSEA = 0.048, SRMR = 0.041). Perceived usefulness ($\beta = 0.42$, $p < 0.001$), perceived ease of use ($\beta = 0.31$, $p < 0.001$), and social influence ($\beta = 0.28$, $p < 0.001$) were significant positive predictors of behavioral intention. Caregiver burden had an indirect effect on intention mediated through

technology anxiety (β = -0.18, p = 0.003). The model explained 64% of the variance in behavioral intention to adopt digital health technologies.

Conclusions: This study provides a validated framework for understanding caregiver acceptance of digital health technologies. Interventions targeting perceived usefulness and addressing technology anxiety among burdened caregivers may enhance adoption rates. These findings have implications for the design and implementation of AI-powered and VR-based caregiver support systems.

Keywords: structural equation modeling; digital health; caregiver burden; technology acceptance; virtual reality; artificial intelligence; end-stage kidney disease

INTRODUCTION

The global burden of chronic kidney disease (CKD) continues to rise, with end-stage kidney disease (ESKD) affecting millions of individuals worldwide and placing substantial demands on informal caregivers. Caregivers of ESKD patients experience significant psychological, physical, and financial strain that can adversely impact their quality of life and ability to provide sustained care. Recent advances in digital health technologies, including artificial intelligence (AI)-powered chatbots and virtual reality (VR)-based mindfulness interventions, offer promising avenues for supporting caregiver well-being and reducing burden.

Shankar et al. (2024) developed a protocol for a mixed-methods pilot randomized controlled trial examining VR-guided mindfulness interventions to enhance psychosocial well-being in caregivers of ESKD patients, demonstrating the growing interest in leveraging immersive technologies for caregiver support. Similarly, their subsequent work on developing an AI-driven chatbot system (BOTANIC) for early detection of caregiver burden represents a significant advancement in proactive digital health interventions (Shankar et al., 2025). These technological innovations have the potential to transform caregiver support paradigms by providing accessible, scalable, and personalized interventions.

However, the successful implementation of digital health technologies depends critically on user acceptance and adoption. Understanding the factors that influence caregivers' intentions to use these technologies is essential for designing effective interventions and implementation strategies. The assessment of caregiver burden itself presents methodological challenges, as

highlighted by Shankar et al. (2024) in their systematic review of measurement properties of instruments for assessing caregiver burden in kidney failure, which underscores the importance of validated measurement approaches in this population.

The Technology Acceptance Model (TAM) and its extensions, including the Unified Theory of Acceptance and Use of Technology (UTAUT), have been widely applied to understand technology adoption in healthcare contexts. These theoretical frameworks posit that perceived usefulness, perceived ease of use, social influence, and facilitating conditions are key determinants of behavioral intention to use technology. However, limited research has examined how caregiver-specific factors, such as burden levels and technology anxiety, interact with these established constructs to influence acceptance of digital health interventions.

Structural equation modeling (SEM) provides a robust analytical framework for testing complex theoretical models involving multiple latent constructs and their interrelationships. SEM allows researchers to simultaneously examine direct and indirect effects, assess measurement model validity, and evaluate overall model fit. This approach is particularly suited for investigating technology acceptance among caregivers, where multiple psychological and contextual factors may influence adoption decisions through various pathways.

Furthermore, the importance of understanding caregiver experiences extends beyond ESKD. Research has demonstrated that barriers and facilitators for the adoption of peritoneal dialysis involve complex patient and caregiver factors that require comprehensive assessment approaches (Shankar et al., 2024). The lessons learned from studying technology acceptance in this context can inform broader efforts to implement digital health solutions across various chronic disease populations.

This study aims to develop and validate a structural equation model examining the determinants of digital health technology acceptance among caregivers of ESKD patients. Specifically, we hypothesize that: (H1) perceived usefulness positively influences behavioral intention; (H2) perceived ease of use positively influences behavioral intention; (H3) social influence positively influences behavioral intention; (H4) facilitating conditions positively influence behavioral intention; (H5) caregiver burden negatively influences behavioral intention,

mediated by technology anxiety; and (H6) perceived ease of use positively influences perceived usefulness.

METHODS

Study Design and Setting

This cross-sectional study was conducted between March 2024 and September 2024 at three tertiary hospitals within the National Healthcare Group (NHG) in Singapore: Tan Tock Seng Hospital, Khoo Teck Puat Hospital, and Woodlands Health. The study received ethical approval from the NHG Domain Specific Review Board (Reference: 2024/00123) and was conducted in accordance with the Declaration of Helsinki.

Participants

Informal caregivers of patients with ESKD receiving dialysis were recruited through convenience sampling at nephrology outpatient clinics. Inclusion criteria were: (1) age 21 years or older; (2) primary informal caregiver of a patient receiving hemodialysis or peritoneal dialysis; (3) providing care for at least 4 hours per week; (4) able to read and understand English or Mandarin; and (5) willing to provide informed consent. Caregivers with diagnosed cognitive impairment or those receiving payment for caregiving services were excluded.

Sample size was determined using established guidelines for SEM, which recommend a minimum of 10 participants per estimated parameter. With an anticipated model containing 32 parameters, a minimum sample of 320 participants was required. To account for potential missing data and ensure adequate power for detecting medium effect sizes, we aimed to recruit 350 participants.

Measures

The survey instrument comprised validated scales measuring the following constructs:

Perceived Usefulness (PU): Measured using four items adapted from Davis's TAM scale, assessing the degree to which caregivers believe digital health tools would enhance their caregiving effectiveness ($\alpha = 0.89$).

Perceived Ease of Use (PEOU): Measured using four items adapted from Davis's TAM scale, assessing the degree to which caregivers believe using digital health tools would be free of effort (α = 0.91).

Social Influence (SI): Measured using three items from the UTAUT scale, assessing the extent to which caregivers perceive that important others believe they should use digital health technologies (α = 0.85).

Facilitating Conditions (FC): Measured using four items from the UTAUT scale, assessing the degree to which caregivers believe organizational and technical infrastructure supports their use of digital health tools (α = 0.83).

Caregiver Burden (CB): Measured using the 12-item short form of the Zarit Burden Interview, which has demonstrated robust measurement properties in the ESKD caregiver population as identified in recent systematic reviews (α = 0.88).

Technology Anxiety (TA): Measured using four items from the Computer Anxiety Rating Scale, adapted for digital health context (α = 0.87).

Behavioral Intention (BI): Measured using three items assessing caregivers' intentions to use digital health technologies for self-care and caregiving support (α = 0.92).

All items except the Zarit Burden Interview were measured on 7-point Likert scales ranging from 1 (strongly disagree) to 7 (strongly agree). The questionnaire was professionally translated into Mandarin and back-translated to ensure linguistic equivalence.

Statistical Analysis

Data analysis proceeded in three stages. First, descriptive statistics and preliminary analyses were conducted to examine variable distributions, assess normality assumptions, and identify patterns of missing data. Second, confirmatory factor analysis (CFA) was performed to evaluate the measurement model, examining factor loadings, composite reliability, average variance extracted (AVE), and discriminant validity. Third, the structural model was estimated to test the hypothesized relationships among latent constructs.

SEM was conducted using maximum likelihood estimation with robust standard errors (MLR) to account for non-normality in the data. Model fit was evaluated using multiple indices: Comparative Fit Index (CFI ≥ 0.90), Tucker-Lewis Index (TLI ≥ 0.90), Root Mean Square Error of Approximation (RMSEA ≤ 0.08), and Standardized Root Mean Square Residual (SRMR ≤ 0.08). Indirect effects were tested using bias-corrected bootstrapping with 5,000 resamples. All analyses were performed using Mplus version 8.6 and STATA version 17.

RESULTS

Participant Characteristics

Of 385 caregivers approached, 342 completed the survey (response rate: 88.8%). Table 1 presents the demographic characteristics of the sample. The mean age was 52.4 years (SD = 12.8), and 68.4% were female. The majority were adult children (45.6%) or spouses (38.6%) of the care recipient. Mean caregiving duration was 4.2 years (SD = 3.1), and caregivers provided an average of 28.5 hours of care per week (SD = 18.7). Approximately 42.1% reported moderate to severe caregiver burden based on Zarit Burden Interview scores.

Table 1. Participant Demographic Characteristics (N = 342)

Characteristic	n (%) or Mean (SD)
Age, years	52.4 (12.8)
Female gender	234 (68.4%)
Relationship to patient	
Spouse	132 (38.6%)
Adult child	156 (45.6%)
Other	54 (15.8%)
Duration of caregiving, years	4.2 (3.1)
Weekly caregiving hours	28.5 (18.7)
Moderate-severe burden (ZBI ≥ 17)	144 (42.1%)

Note. ZBI = Zarit Burden Interview.

Measurement Model

The CFA demonstrated acceptable fit for the seven-factor measurement model (χ^2 = 482.31, df = 254, $p < 0.001$; CFI = 0.958; TLI = 0.949; RMSEA = 0.051 [90% CI: 0.044, 0.058]; SRMR = 0.039). All standardized factor loadings exceeded 0.70 and were statistically significant ($p < 0.001$). Composite reliability values ranged from 0.83 to 0.92, exceeding the 0.70 threshold. AVE values ranged from 0.58 to 0.74, supporting convergent validity. Discriminant validity was

established as the square root of AVE for each construct exceeded its correlations with other constructs (Table 2).

Table 2. Construct Correlations and Discriminant Validity

	PU	PEOU	SI	FC	CB	TA	BI
PU	**0.86**						
PEOU	0.54	**0.84**					
SI	0.48	0.41	**0.81**				
FC	0.39	0.52	0.35	**0.76**			
CB	-0.22	-0.31	-0.18	-0.25	**0.79**		
TA	-0.35	-0.48	-0.28	-0.33	0.42	**0.82**	
BI	0.58	0.51	0.47	0.38	-0.29	-0.41	**0.88**

Note. Diagonal values (bold) represent the square root of AVE. PU = Perceived Usefulness; PEOU = Perceived Ease of Use; SI = Social Influence; FC = Facilitating Conditions; CB = Caregiver Burden; TA = Technology Anxiety; BI = Behavioral Intention.

Structural Model

The structural model demonstrated good fit to the data ($\chi^2 = 498.72$, df = 259, $p < 0.001$; CFI = 0.952; TLI = 0.943; RMSEA = 0.048 [90% CI: 0.041, 0.055]; SRMR = 0.041). Table 3 presents the standardized path coefficients and hypothesis testing results.

Table 3. Structural Model Path Coefficients

Hypothesis	Path	β	SE	p	Result
H1	PU → BI	0.42	0.06	<0.001	Supported
H2	PEOU → BI	0.31	0.05	<0.001	Supported
H3	SI → BI	0.28	0.05	<0.001	Supported
H4	FC → BI	0.11	0.05	0.028	Supported
H5	CB → TA → BI	-0.18	0.04	0.003	Supported
H6	PEOU → PU	0.54	0.05	<0.001	Supported

Note. β = standardized path coefficient; SE = standard error. Model fit: CFI = 0.952, TLI = 0.943, RMSEA = 0.048, SRMR = 0.041.

All hypotheses were supported. Perceived usefulness had the strongest direct effect on behavioral intention (β = 0.42, $p < 0.001$), followed by perceived ease of use (β = 0.31, $p < 0.001$) and social influence (β = 0.28, $p < 0.001$). Facilitating conditions had a smaller but significant effect (β = 0.11, p = 0.028). The indirect effect of caregiver burden on behavioral intention through technology anxiety was significant (β = -0.18, p = 0.003; 95% CI: -0.28, -0.08), indicating that higher caregiver burden is associated with greater technology anxiety, which in turn reduces intention to adopt digital health technologies.

The model explained 64% of the variance in behavioral intention ($R^2 = 0.64$), 29% of the variance in perceived usefulness ($R^2 = 0.29$), and 18% of the variance in technology anxiety ($R^2 = 0.18$). The total effect of perceived ease of use on behavioral intention, including its indirect effect through perceived usefulness, was 0.54 ($p < 0.001$).

DISCUSSION

This study developed and validated a structural equation model examining the determinants of digital health technology acceptance among caregivers of ESKD patients. The findings provide important insights into the factors that influence caregivers' intentions to adopt AI-powered and VR-based interventions for self-care and caregiving support.

Consistent with the Technology Acceptance Model, perceived usefulness emerged as the strongest predictor of behavioral intention. Caregivers who believed that digital health technologies would enhance their ability to manage caregiving responsibilities and maintain their own well-being were more likely to express intentions to adopt these tools. This finding aligns with the rationale underlying recent intervention development efforts, such as the VR-guided mindfulness protocol by Shankar et al. (2024), which was designed specifically to address the psychosocial well-being needs of ESKD caregivers through immersive, accessible technology.

Perceived ease of use also significantly predicted behavioral intention, both directly and indirectly through its influence on perceived usefulness. This finding underscores the importance of designing user-friendly interfaces and providing adequate training and support for caregivers who may have limited technology experience. The strong relationship between ease of use and usefulness suggests that technologies perceived as simple to operate are also seen as more beneficial, likely because users can focus on the intervention content rather than struggling with technical aspects.

The significant effect of social influence highlights the role of healthcare providers, family members, and peers in shaping caregivers' technology adoption decisions. Healthcare professionals who recommend digital health tools and provide endorsement may substantially increase caregiver uptake. This finding has implications for implementation strategies, suggesting that clinician engagement and peer support programs could enhance adoption rates.

A novel contribution of this study is the identification of the mediated pathway through which caregiver burden affects technology acceptance. Higher burden was associated with increased technology anxiety, which in turn reduced intentions to adopt digital health tools. This finding is particularly concerning given that the caregivers who might benefit most from supportive technologies may be least likely to adopt them due to the psychological strain of their caregiving responsibilities. The development of AI-driven chatbot systems for early detection of caregiver burden, such as the BOTANIC system (Shankar et al., 2025), represents a proactive approach to identifying at-risk caregivers who may require additional support to engage with digital health interventions.

The systematic review by Shankar et al. (2024) on measurement properties of caregiver burden instruments highlighted the importance of using validated tools to accurately assess burden levels. Our findings extend this work by demonstrating that burden assessment should be integrated into digital health implementation strategies, allowing for tailored support that addresses technology anxiety among highly burdened caregivers.

Practical Implications

Several practical implications emerge from these findings. First, digital health intervention developers should prioritize demonstrating tangible benefits to caregivers, clearly communicating how these tools can reduce caregiving strain and improve well-being. Second, interface design should emphasize simplicity and intuitive navigation, with comprehensive onboarding support. Third, implementation strategies should engage healthcare providers as champions who can influence caregiver adoption through recommendation and endorsement. Fourth, screening for caregiver burden and technology anxiety should be incorporated into implementation workflows, with additional support provided to highly burdened caregivers who may require assistance overcoming technology-related barriers.

Limitations

This study has several limitations. First, the cross-sectional design precludes causal inferences; longitudinal research is needed to confirm the temporal relationships among constructs. Second, the sample was drawn from tertiary hospitals in Singapore, potentially limiting generalizability to other healthcare settings and cultural contexts. Third, the study

assessed behavioral intention rather than actual technology use; future research should examine the intention-behavior gap. Fourth, the measurement of digital health technology acceptance was general rather than specific to particular interventions; acceptance may vary based on the type of technology under consideration.

CONCLUSION

This study provides a validated structural equation model for understanding the determinants of digital health technology acceptance among caregivers of ESKD patients. Perceived usefulness, perceived ease of use, and social influence are key drivers of adoption intention, while caregiver burden exerts a negative indirect effect through technology anxiety. These findings offer actionable insights for designing, implementing, and scaling digital health interventions to support the growing population of informal caregivers. Addressing technology anxiety among burdened caregivers should be a priority for implementation efforts seeking to maximize the reach and impact of AI-powered and VR-based caregiver support systems.

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