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# Improving Glycemic Control Among Indonesian Urban Adults: A Digital and Behavioral Extension of the Information–Motivation–Behavioral Skills Model

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## Abstract

Management of type 2 diabetes mellitus (T2DM) in Indonesia continues to face challenges due to behavioral, informational, and technological gaps among patients. This study analyzed the influence of self-regulatory competence and information, motivation, family support, and digital health literacy on glycemic control behavior. A cross-sectional survey was conducted from February to April 2025 among 587 adults aged >30 years with T2DM enrolled in the Chronic Disease Management Program at primary health care in six major cities: Jakarta, Surabaya, Yogyakarta, Medan, Makassar, and Banjarmasin. Data were collected through structured questionnaires and analyzed using partial least squares structural equation modeling. The findings revealed that motivation, followed by information and family support, exerted the strongest effect on self-regulatory competence. Self-regulatory competence significantly predicted glycemic control behavior, whereas digital health literacy directly improved behavior and strengthened the effect of self-regulatory competence. These results suggested that behavioral competence and digital engagement were mutually reinforcing capacities essential for the self-management of chronic diseases. This study extends the Information–Motivation–Behavioral Skills model by incorporating digital and social dimensions, offering a contextually grounded framework for strengthening diabetes care in Indonesia's urban health system.

**Keywords:** diabetes, health behavior, health literacy, self-management

## Introduction

Type 2 diabetes mellitus (T2DM) is now one of Indonesia's most pressing public health challenges, contributing increasingly to the burden of noncommunicable disease mortality. In 2024, more than 10 million Indonesians were estimated to live with diabetes. Wahidin *et al.* projected that annual deaths attributable to diabetes would increase from 433,752 in 2020 to 944,468 by 2045.<sup>1</sup> The 2018 Indonesian Basic Health Research reported a diabetes prevalence of 8.5 % based on blood glucose measurement, equivalent to approximately 20.4 million persons.<sup>2</sup> Recent data show an increase to approximately 10.6 % in 2021, with modeling projections suggesting further growth to over 16% by 2045, underscoring a substantial upward trajectory in diabetes burden.<sup>3</sup> Alarmingly, many cases remain undetected: analyses of the Indonesian Basic Health Research data suggest that up to 80% of diabetes cases are undiagnosed prior to the survey. The combination of rising prevalence, increasing mortality, and pervasive underdiagnosis highlights that achieving optimal glycemic control is not solely a clinical goal but a societal imperative requiring integrated behavioral, diagnostic, and public health strategies.<sup>1</sup>

Glycemic control behaviors, including consistent medication adherence, dietary regulation, physical activity, and regular blood sugar monitoring, play a central role in preventing complications and improving long-term outcomes.<sup>4,5</sup> However, maintaining such behaviors not only requires access to medical care but also demands a sustained commitment from individuals to regulate their own actions in the context of competing social pressures, limited health literacy, and evolving technological landscapes. In Indonesia, where health system infrastructure is unevenly distributed and cultural values emphasize familial interdependence, a contextualized and multifactorial approach is needed to understand the behavioral determinants of diabetes self-care.

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Previous studies have attempted to explain diabetes self-management behavior using theoretical models such as the information-motivation-behavioral skills (IMB) model.<sup>6-8</sup> The IMB model, originally developed to explain how individuals adopt and maintain health behaviors, has been widely applied to chronic disease contexts, including diabetes.<sup>9,10</sup> The model posits that individuals are more likely to perform health-related behaviors when they are adequately informed, internally and socially motivated, and equipped with the necessary behavioral skills. Empirical research supports this hypothesis. For instance, Salari *et al.* demonstrated the utility of IMB-based interventions in enhancing health behavior change across multiple domains.<sup>11</sup> In the Indonesian context, a study by Mirzaei-Alavijeh applied the IMB model to analyze diabetes self-management among patients in Jakarta, finding that information and motivation significantly influenced behavioral skills, which in turn improved self-care behavior.<sup>9</sup> While this model is conceptually robust, it does not fully reflect the social and technological realities of chronic disease management in Indonesia today.

Current applications of the IMB model in diabetes mellitus research exhibit important limitations that merit further refinement. First, the behavioral skills component is often narrowly operationalized to discrete tasks, such as medication adherence or glucose checking, without capturing the broader self-regulation domain (e.g., goal-setting, monitoring, and adaptive strategy use). Although health psychologists have long emphasized that self-regulatory processes are critical for sustaining behavior change,<sup>12</sup> few IMB studies on diabetes mellitus have integrated this extended construct. Second, the rapid diffusion of digital tools in diabetes care stands in stark contrast to the scarcity of models that incorporate digital health literacy. In a recent structural equation modeling study in rural China, digital health literacy exerted both direct and indirect effects on self-management behavior for chronic diseases, mediated by social support and psychological distress.<sup>13</sup> Another study has also highlighted the influence of sociodemographic factors, device accessibility, and social support on digital health literacy among older adults with chronic disease.<sup>14</sup> Third, family support remains undisintegrated in IMB frameworks despite its relevance in diabetes self-management. A recent qualitative study in Indonesia revealed how family members contribute through emotional encouragement, shared planning, reminders, and accompaniment during appointments.<sup>15</sup> Moreover, a 2023 study confirmed a consistent positive role of family in supporting adherence to self-care practices.<sup>16</sup> These converging strands suggest the need to extend the IMB model to include self-regulatory competence, digital health literacy, and culturally embedded relational support to more fully explain long-term glycemic management.

Taken together, these gaps suggest the need for an extended behavioral model that reflects the multifaceted influences on glycemic control in Indonesia. This study aimed to fill that void by proposing an extended version of the IMB model. The new framework includes digital health literacy and family support as additional determinants of glycemic control behaviors and reconceptualizes behavioral skills as self-regulatory competence. Through this integrative approach, this study examined how information, motivation, family support, and digital health literacy influence self-regulatory competence and how self-regulatory competence shapes glycemic control behavior. The mediating role of self-regulatory competence and the moderating influence of digital health literacy in these pathways were also investigated. This study contributed to both theoretical development and practical intervention design in urban Indonesian contexts using structural equation modeling. Theoretically, the IMB model is refined to better suit the sociotechnical realities of chronic disease management in low- and middle-income countries. Practically, it offers evidence-based insights to inform culturally tailored and digitally supported strategies for improving diabetes care at the community and policy levels.

## Method

This study employed a cross-sectional quantitative design using survey-based data collection to investigate the behavioral determinants of glycemic control among Indonesian adults diagnosed with T2DM. The extended framework, which was developed from the IMB model, incorporated additional constructs, including family support, digital health literacy, and self-regulatory competence, to reflect the complexity of diabetes management in contemporary Indonesian society. The partial least squares structural equation modeling (PLS-SEM) approach was used to test the hypothesized direct, mediating, and moderating effects within the model.

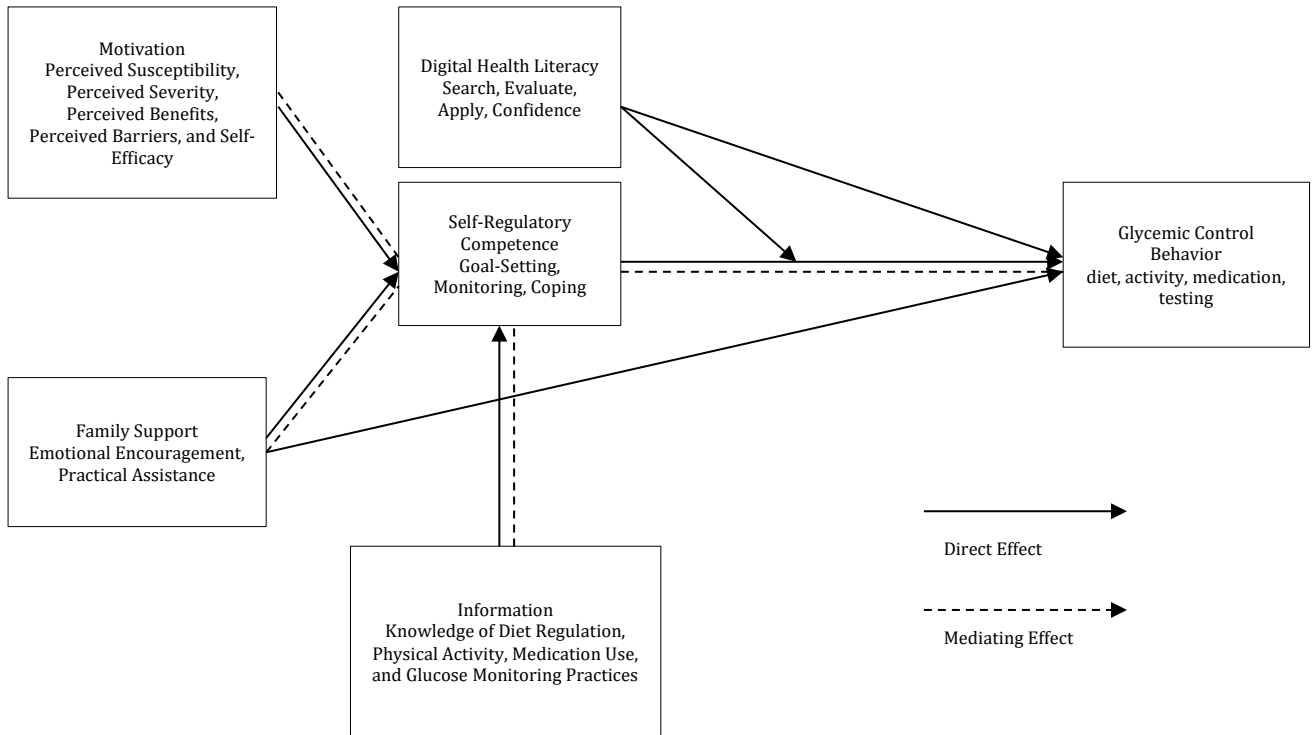


Figure 1. Research Framework

To ensure diversity and national relevance, this study was conducted across six major urban cities in Indonesia: Jakarta, Surabaya, Yogyakarta, Medan, Makassar, and Banjarmasin, selected to represent geographic and sociodemographic variations across the archipelago. Jakarta and Surabaya exemplify highly urbanized areas with advanced health systems, while Yogyakarta is an education and public health innovation hub. Medan and Makassar reflect growing metropolitan regions outside Java, and Banjarmasin illustrates urban communities in resource-constrained settings. This multi-site approach enhances the external validity and representativeness of the findings across Indonesia’s western, central, and eastern regions.

The study population comprised adults ( $\geq 30$  years) diagnosed with T2DM and enrolled in the government’s Chronic Disease Management Program/*Program Pengelolaan Penyakit Kronis* (Prolanis) under the National Health Insurance (NHI) scheme. Eligible participants were active Prolanis members with at least 6 months since diagnosis, able to communicate in the Indonesian language, and willing to provide informed consent. Patients with T1DM, cognitive impairment, or acute complications were excluded.

A multistage proportional sampling design was applied. In the first stage, six provinces were purposively chosen, each represented by one city. Based on active Prolanis implementation, 14 primary health cares (PHCs) were selected, yielding 35–50 respondents per site and 587 valid responses collected between February and April 2025. The minimum sample size was determined according to Hair’s SEM guideline of 10 respondents per indicator, requiring at least 300 participants.<sup>17</sup> Data were obtained through structured questionnaires administered with enumerator assistance to ensure inclusivity for older or low-literacy respondents. Six instruments were used: demographic items and five validated scales measuring information, motivation, family support, digital health literacy, self-regulatory competence, and glycemic control behavior. Measures were adapted from Ambrož *et al.*,<sup>18</sup> the Health Belief Model,<sup>19</sup> the Family Support for Chronic Illness Scale,<sup>20</sup> the eHealth Literacy Scale (eHEALS),<sup>21</sup> Schwarzer’s health action framework,<sup>22</sup> and the Diabetes Self-Management Questionnaire (DSMQ).<sup>23</sup>

Demographic characteristics were collected to provide a descriptive context and allow subgroup comparisons. Age was recorded in years and subsequently categorized into five groups: 30–39, 40–49, 50–59, 60–69, and  $\geq 70$  years, reflecting standard epidemiological classifications in diabetes research. Sex was coded as male or female. Education level was grouped into five categories: no formal education, elementary school, junior high school, senior high school, and higher education (diploma or university degree). Employment status was classified as employed (formal or informal),

unemployed, retired, housewife, or other based on self-reported primary occupation. The duration of diabetes diagnosis was divided into <1 year, 1–5 years, 6–10 years, and >10 years to distinguish between early and long-term experiences of disease management. The residence was coded according to the six selected urban sites (Jakarta, Surabaya, Yogyakarta, Medan, Makassar, and Banjarmasin). These categorical variables were used to summarize the sample's characteristics (Table 1) and to explore potential demographic variations in the constructs of the extended IMB model.

All questionnaire items were translated using the forward–backward method and tested in a pilot survey involving 30 respondents to ensure clarity and cultural appropriateness. Reliability and validity tests were conducted prior to the full analysis. Cronbach's alpha and composite reliability values exceeded 0.7 for all constructs, while the average variance extracted (AVE) values for all latent variables were above 0.5, confirming convergent validity. Discriminant validity was confirmed using the heterotrait–monotrait ratios (HTMT) criterion. Multicollinearity was assessed using variance inflation factors (VIFs), all of which were below 3.3, indicating no critical multicollinearity.

Data analysis was conducted using SmartPLS ver. 4.1.0.8 (licensed) following the standard PLS-SEM procedures. The dataset was first screened for missing values, outliers, and common-method bias, with all VIFs below 3.3. Each construct, information, motivation, family support, digital health literacy, self-regulatory competence, and glycemic control behavior was modeled reflectively, with indicators retained if loadings exceeded 0.708. Composite reliability and rho\_A values were all above 0.70, and the AVE exceeded 0.50, confirming convergent validity. Discriminant validity was supported by HTMT below 0.85. The structural model was tested to obtain standardized path coefficients, t-values, and confidence intervals from 5,000 bootstrap resamples. Bias-corrected bootstrapping was used to verify mediation effects, and moderation by digital health literacy was examined using the product-indicator approach with conditional slope analysis. Model quality was assessed using  $R^2$ ,  $f^2$ , the standardized root means square residual (SRMR), and PLSpredict for predictive validity.

## Results

This study included 587 adults aged 30–79 years ( $M = 56.3$ ,  $SD = 9.7$ ). Most participants were aged 50–59 years (37.1%) or 60–69 years (28.6%), confirming that the sample primarily represented middle-aged and older adults, the main targets of Prolanis in Indonesia. Women constituted 66.3% of the respondents, reflecting a pattern observed in Prolanis participation where females were generally more active in health monitoring activities. Educational attainment varied: 36.1% completed senior high school, 20.6% had tertiary education, 21.6% had only elementary schooling, and 3.9% reported no formal education. Regarding employment, 31.9% were housewives, 28.5% were employed, 15.8% were retired, and 13.3% were unemployed, indicating a high proportion of economically inactive individuals who may rely on family support for diabetes care. Nearly all participants had managed diabetes for more than one year, with 45.7% diagnosed for 1–5 years and 35.9% diagnosed for 6–10 years. Geographically, respondents were well distributed across Jakarta, Surabaya, Yogyakarta, Medan, Makassar, and Banjarmasin, ensuring a diverse representation of Indonesia's urban health contexts.

Respondents demonstrated moderate to high self-management engagement. The highest mean score was recorded for information ( $M = 4.12$ ,  $SD = 0.52$ ), followed by motivation ( $M = 3.97$ ,  $SD = 0.61$ ) and self-regulatory competence ( $M = 3.92$ ,  $SD = 0.57$ ), indicating strong awareness and behavioral capability. Family support was moderate ( $M = 3.85$ ,  $SD = 0.74$ ), whereas digital health literacy ( $M = 3.64$ ,  $SD = 0.69$ ) remained the lowest, suggesting ongoing barriers to the effective use of digital health information. Glycemic control behavior ( $M = 3.81$ ,  $SD = 0.65$ ) reflected generally good adherence but left room for improvement.

Table 1 presents the results of the internal consistency and reliability analysis. All constructs demonstrated strong reliability, with Cronbach's alphas exceeding the recommended threshold of 0.70, indicating consistent responses across items for each construct. Moreover, the CR values ranged from 0.87 to 0.91, well above the conventional cutoff of 0.70, suggesting that each set of items reliably represents its respective latent variable. These findings confirmed the measurement model's internal consistency and justify evaluating convergent and discriminant validity.

**Table 1. Internal Consistency Reliability**

Construct	Number of Items	Cronbach's Alpha	Composite Reliability
Information	8	0.83	0.88
Motivation	10	0.87	0.90
Family Support	6	0.82	0.87
Digital Health Literacy	8	0.85	0.89
Self-Regulatory Competence	9	0.88	0.91
Glycemic Control Behavior	8	0.86	0.90

Convergent validity was evaluated using the AVE for each latent construct. As shown in Table 2, all AVEs exceeded the recommended threshold of 0.50, indicating that each latent construct explained more than 50% of the variance in the observed indicators. The highest AVE was observed in digital health literacy (0.64), suggesting particularly strong item loadings in that domain. These results confirmed that the indicators converge adequately to their intended constructs, thereby supporting convergent validity within the measurement model.

**Table 2. Convergent Validity**

Construct	Average Variance Extracted
Information	0.59
Motivation	0.62
Family Support	0.61
Digital Health Literacy	0.64
Self-Regulatory Competence	0.60
Glycemic Control Behavior	0.58

Discriminant validity was evaluated using the HTMT, which compares correlations among the constructs. All HTMT values were below the conservative threshold of 0.85, indicating strong discriminant validity (Table 3). The highest HTMT value was observed between self-regulatory competence and glycemic control behavior (0.69), which was theoretically expected given the conceptual link between planning/monitoring abilities and health behavior. No construct exceeded the critical thresholds, confirming that the model's latent variables are empirically distinct from one another.

**Table 3. Discriminant Validity**

Constructs	1	2	3	4	5	6
1. Information	—					
2. Motivation	0.63	—				
3. Family Support	0.54	0.60	—			
4. Digital Health Literacy	0.58	0.56	0.52	—		
5. Self-Regulatory Competence	0.66	0.68	0.61	0.65	—	
6. Glycemic Control Behavior	0.59	0.63	0.57	0.61	0.69	—

All predictor variables in the structural model were tested for multicollinearity, with VIF values ranging from 1.87 to 2.64, well below the recommended threshold of 3.3. This indicated that the constructions contributed a unique explanatory power and that the estimated path coefficients were statistically reliable. The hypothesis testing results in Table 4 provide strong empirical support for the extended IMB model in the Indonesian context. Among the direct effects, self-regulatory competence had the highest standardized path coefficient ( $\beta = 0.43$ ,  $p$ -value  $< 0.001$ ), underscoring its foundational role in translating psychosocial inputs into actual health behavior.

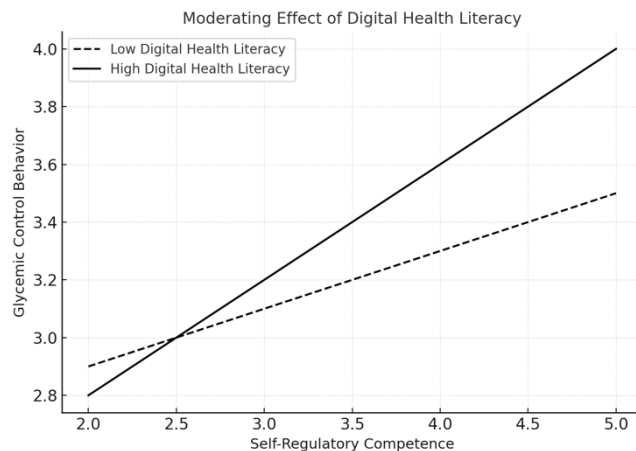
Furthermore, motivation emerged as a stronger predictor of self-regulatory competence ( $\beta = 0.34$ ) than information ( $\beta = 0.21$ ) or family support ( $\beta = 0.19$ ), suggesting that internal drive and perceived value of glycemic control played a more decisive role in fostering behavioral skills than knowledge alone. These patterns reflected the psychological and social complexity of managing chronic conditions, such as diabetes, where emotional and motivational engagement often precedes sustained self-regulation. The analysis confirmed partial mediation through self-regulatory competence for all three antecedents, information, motivation, and family support (H7–H9). These results reinforced the theoretical assumption within the model that behavioral change occurs through an intermediary phase of internalized capability rather than through direct influence alone.

Finally, the last hypothesis (H10) tested the moderating role of digital health literacy. It yielded a significant interaction effect ( $\beta = 0.11$ ,  $p$ -value = 0.013), meaning that individuals with higher digital health literacy experienced a stronger positive relationship between self-regulatory competence and glyceemic control behavior. In other words, the benefits of planning, monitoring, and adapting one’s behavior were amplified when individuals also have the digital capacity to access, interpret, and apply health-related information from online sources and mobile apps.

**Table 4. Hypothesis Testing Results**

Code	Path	$\beta$	t-value	p-value
H1	Information → Self-Regulatory Competence	0.21	4.36	<0.001
H2	Motivation → Self-Regulatory Competence	0.34	6.92	<0.001
H3	Family Support → Self-Regulatory Competence	0.19	3.88	<0.001
H4	Self-Regulatory Competence → Glycemic Control Behavior	0.43	8.21	<0.001
H5	Family Support → Glycemic Control Behavior	0.16	3.07	0.002
H6	Digital Health Literacy → Glycemic Control Behavior	0.22	4.48	<0.001
H7	Information → Self-Reg. Comp. → Glycemic Control Behavior	0.09	3.25	0.001
H8	Motivation → Self-Reg. Comp. → Glycemic Control Behavior	0.15	4.86	<0.001
H9	Family Support → Self-Reg. Comp. → Glycemic Control Behavior	0.08	2.94	0.003
H10	Self-Reg. Comp. × Digital Health Literacy → Glycemic Control Behavior	0.11	2.48	0.013

Figure 2 illustrates this interaction effect. The solid line represents individuals with high digital health literacy, whereas the dashed line represents those with low digital health literacy. The steeper slope of the high digital health literacy group visually confirms that self-regulatory competence has a stronger positive impact on glyceemic control among individuals with higher levels of digital engagement. In contrast, those with limited digital health literacy experience a weaker association, indicating that barriers to accessing and applying digital health information may constrain their ability to translate behavioral competence into effective self-care. This finding highlighted the importance of digital inclusion in chronic disease management, particularly in a country such as Indonesia, where digital health literacy platforms (e.g., PeduliLindungi, Halodoc, and BPJS digital services) are becoming integral to health service delivery. Diabetes education programs should not only develop behavioral competence but also invest in improving patients’ digital health navigation skills to maximize self-management outcomes.



**Figure 2. Moderating the Effect of Digital Health Literacy Platforms**

## Discussion

This study examined how information, motivation, family support, and digital health literacy influence glyceemic control behaviors among Indonesians with T2DM, with self-regulatory competence as a mediating factor. The findings provided new insights into how behavioral change mechanisms function in a rapidly digitizing yet socioculturally complex setting through extending the IMB model (Figure 1). A central contribution of this study was in confirming that self-regulatory competence is the most proximal determinant of glyceemic control behavior. Consistent with prior IMB-based applications,<sup>9,11</sup> this study’s findings showed that information and motivation alone are insufficient unless patients can regulate, monitor, and adapt their behaviors. Other studies have consistently identified behavioral regulation as the most proximal determinant of effective self-care.<sup>24,25</sup> However, unlike earlier studies that narrowly conceptualized behavioral skills as task-specific routines, the present evidence suggests that framing them as broader self-regulatory

competence captures the dynamic and adaptive nature of long-term diabetes management. This reconceptualization strengthens the IMB model's explanatory power and aligns with recent behavioral health theories emphasizing autonomy and goal-setting as key determinants of chronic care adherence.<sup>12</sup>

The role of digital health literacy significantly extended the original IMB framework. It not only exerted a direct influence on glycemic control but also moderated the pathway from self-regulatory competence to behavior, amplifying its impact among digitally literate patients. This moderating role has been underexplored in previous diabetes studies but is highly relevant in Indonesia, where the digitalization of health services is expanding unevenly.<sup>26</sup> Behavioral competence becomes most effective when supported by the digital capacity to navigate health applications, online consultations, and BPJS-integrated platforms. From a critical perspective, this synergy between behavioral and digital capacities suggests that unless accompanied by behavioral empowerment strategies, technological infrastructure alone cannot improve chronic disease outcomes. Conversely, behavioral interventions that disregard digital inequities may inadvertently widen the self-care gap between urban and digitally underserved populations.<sup>26</sup>

Motivation emerged as a stronger predictor of self-regulatory competence than either information or family support within the psychosocial domain. These results aligned with self-determination theory,<sup>24</sup> which posits that intrinsic motivation rooted in perceived autonomy and internalized goals is central to sustainable health behaviors. The implication is that diabetes interventions in Indonesia may achieve limited outcomes if they remain predominantly informational, as many community education programs currently are, without integrating motivational enhancement and self-efficacy development. A critical reflection here concerns the cultural expectation that health information alone will induce compliance, which the present findings challenge by showing that emotional engagement and perceived control are more powerful behavioral catalysts.

Contrary to the expectations derived from the collectivist cultural frameworks, family support played a more modest role. Although it contributed directly to glycemic control and indirectly through self-regulatory competence, its effect was weaker than that of motivation. It challenges the assumption that collectivist family structures automatically guarantee health-promoting support. Some family interactions may be overprotective or directive, thereby undermining autonomy and self-confidence, as evidenced in prior studies.<sup>27,28</sup> These findings underscore that the quality of family engagement matters more than its mere presence. Therefore, future interventions should focus on cultivating constructive family support that encourages empathy, shared decision-making, and respect for patient autonomy rather than assuming uniform benefits of family involvement.

The integration of self-regulatory competence, digital health literacy, and culturally grounded family support makes the extended IMB model particularly relevant to Indonesia's urban healthcare transformation. This framework bridges individual behavioral capacity with sociotechnical factors and offers insights applicable to other low- and middle-income contexts undergoing digital health transitions. The multi-city design of the study across six provinces enhances the representativeness, while the validated instruments and robust PLS-SEM procedures strengthen the methodological rigor. The limitations of this study included its cross-sectional nature, reliance on self-reported data, and focus on urban participants, which may restrict causal inference and generalizability to rural populations. Future research should employ longitudinal or mixed-method approaches, integrate clinical indicators such as HbA1c, and test interventions combining digital literacy training with motivational enhancement. Overall, this study affirmed that sustainable diabetes management requires interventions that foster motivation, self-regulation, and digital inclusion, ensuring that technological innovation translates into behavioral and health improvements.

## **Conclusion**

This study highlights the importance of self-regulatory competence in improving glycemic control among Indonesian adults with T2DM, especially when supported by adequate digital health literacy. The extended IMB model demonstrates that behavioral competence and digital engagement function synergistically to strengthen diabetes self-management. Primary health care and Prolanis facilitators should integrate digital literacy training within routine programs to enhance outcomes. At the same time, the Indonesian Ministry of Health and BPJS Kesehatan should ensure that digital platforms are accessible, user-friendly, and culturally appropriate. Therefore, policymakers and health practitioners should promote multisectoral initiatives that combine behavioral empowerment, digital inclusion, and family-based support to sustain effective diabetes care in Indonesia.

### Abbreviations

T2DM: type 2 diabetes mellitus; IMB: information–motivation–behavioral skills; PLS-SEM: partial least squares structural equation modeling; Prolanis: Program Pengelolaan Penyakit Kronis/Chronic Disease Management Program; PHC: primary health care; AVE: average variance extracted; HTMT: heterotrait–monotrait ratios; VIF: variance inflation factors.

### Ethics Approval and Consent to Participate

Written informed consent was obtained from all participants. The participants were assured of confidentiality, and their participation or refusal did not affect their access to medical treatment or Prolanis services. This study received ethical clearance from the Ethics Committee of STIKES Gunung Sari, Makassar, Indonesia. The approval was granted under approval number 112/STIKES-GS/MKS/V/2025, issued by the Director of STIKES, Gunung Sari. The committee reviewed and approved the study protocol in accordance with applicable national regulations and institutional research ethics guidelines.

### Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

### Availability of Data and Materials

The data of this study are available upon reasonable request.

### Author's Contribution

IA did all the data collection, data processing, and wrote the manuscript.

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