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The Development and Evaluation of the Application for Assessing the Fall Risk Factors and the Suggestion to Prevent Falls in Older Adults

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Abstract: Falls are a major health concern for older adults, often leading to injuries and reduced independence. This study develops and evaluates a mobile application integrating two validated fall-risk assessment tools—the Stay Independent Brochure (SIB) and the 44-question Thai Home Falls Hazards Assessment Tool (Thai-HFHAT). The app utilizes a cloud-based architecture with a relational database for real-time analytics and user tracking. In Phase 1, 30 healthcare professionals assessed the app's technical performance and user experience using a modified System Usability Scale (SUS), achieving a high usability score of 85.2. In Phase 2, 67 older adults used the app for self-assessment, with test–retest reliability evaluated over one week. The app showed strong reliability, with intraclass correlation coefficients (ICCs) of 0.80 for the SIB (Thai-version) and 0.77 for the Thai-HFHAT. Cloud-hosted analytics revealed significant correlations between fall occurrences and both SIB ($r = 0.657$, $p < 0.001$) and Thai-HFHAT scores ($r = 0.709$, $p < 0.001$), demonstrating the app's predictive validity. The findings confirm the app's effectiveness as a self-assessment tool for fall-risk screening among older adults, combining clinical validity with high usability. The integration of culturally adapted tools into a cloud-supported platform demonstrates the value of informatics in geriatric care. Future studies should focus on expanding the app's reach, incorporating AI-driven risk prediction, enhancing interoperability with electronic health records (EHRs), and improving long-term user engagement to maximize its impact in community settings.

Keywords: mobile health; fall risk assessment; health informatics; digital health; AI in healthcare

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Received: 22 April 2025
Revised: 28 May 2025
Accepted: 3 June 2025
Published: 5 June 2025

Citation: Lektip, C.; Jiamjarasrangsi, W.; Kaewrat, C.; Nawarat, J.; Rungruangbaiyok, C.; Mackenzie, L.; Somsak, V.; Wannaprom, N. The Development and Evaluation of the Application for Assessing the Fall Risk Factors and the Suggestion to Prevent Falls in Older Adults. *Informatics* **2025**, *12*, 53. https://doi.org/10.3390/informatics12020053

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1. Introduction

Falls represent a significant public health concern among older adults globally. According to the World Health Organization, 28–35% of individuals over 65 experience at least one fall annually, with this incidence increasing to 32–42% in those over 70 [1]. This growing prevalence correlates with the expanding global aging population. Falls frequently result in physical injuries, reduced independence, and elevated healthcare costs [2]. In Thailand specifically, the Department of Disease Control projected that falls would account for 27% of deaths among older adults between 2017 and 2021, with an estimated mortality rate of 50 per 100,000 individuals [3].

Fall risk factors are categorized as intrinsic or extrinsic. Intrinsic factors include advanced age, previous falls, muscle weakness, gait and balance problems, poor vision, postural hypotension, chronic conditions, and fear of falling. Extrinsic factors encompass environmental hazards such as inadequate lighting, uneven flooring, unsecured rugs, and problematic stairs [4]. Studies in Thailand have identified specific environmental risk factors, including slippery bathroom areas, bathrooms located outside the home [5], unsecured carpets, low chairs, damaged corridors, and obstructive garden features [6]. Fall prevention can be effectively addressed through home hazard screening and environmental modifications, enabling safer aging-in-place [7,8].

Various fall risk screening tools exist, differing in assessment methods, scoring systems, duration, target users, and language options. In Thailand, the Stay Independent Brochure (SIB) has been validated for intrinsic fall risk screening, demonstrating good content validity and excellent test–retest and inter-rater reliability. Its convergent validity with established measures like the Timed Up and Go (TUG) and Berg Balance Scale (BBS) tests were statistically significant ($p < 0.001$) [9]. For environmental risk assessment, the 44-question Thai Home Falls Hazards Assessment Tool (Thai-HFHAT) has shown high reliability with an adjusted hazard ratio of 1.26 (95% CI: 1.20–1.33), sensitivity of 0.93, specificity of 0.72, and area under the receiver operating characteristic curve of 0.897 [10]. However, implementation challenges persist: the SIB is typically paper-based and may be inaccessible to tech-savvy users, while the Thai-HFHAT is lengthy and often requires assistance. These limitations highlight the need for user-friendly digital solutions that integrate both intrinsic and extrinsic risk assessments.

The proliferation of mobile health applications [11] and increasing global internet connectivity [12] have created unprecedented opportunities for digital delivery of home-based support. Thailand's rapidly expanding internet access across all regions signals the country's transition to a digital era [13]. Most Thai older adults use mobile phones, with 50% preferring LINE for communication and information access and 16% using Facebook for news and social updates [14]. Digital health approaches have already demonstrated effectiveness in self-management of various non-communicable diseases [15–17].

Several mobile health applications support fall prevention among older adults, including balance training programs (Steady, Nymbl), risk assessment tools (Falls Risk, Prevent IT), and sensor-based systems (Fall Sensing, Prevent IT) [18–21]. However, these solutions have significant limitations: (1) they are often designed for clinician rather than older adult use; (2) they typically focus solely on intrinsic risk factors, neglecting environmental hazards; (3) they lack cultural adaptation for implementation in Thailand and other low- and middle-income countries; and (4) they do not incorporate validated assessment tools like the SIB and Thai-HFHAT.

This study addresses these gaps through the development and evaluation of a mobile application integrating the SIB and Thai-HFHAT into a single, user-friendly platform specifically tailored for older adults in Thailand. Our key contributions include: (1) developing a cloud-based application that screens both intrinsic and extrinsic fall risk factors; (2) im-

plementing user-centered design features such as adjustable font sizes and gesture-based navigation to enhance accessibility; (3) empirically evaluating test–retest reliability, construct validity, and user satisfaction among healthcare professionals and older adults; and (4) demonstrating predictive validity through correlations with real-world fall incidents and TUG test performance. In contrast to existing tools, our application delivers localized content tailored to Thai users and provides personalized fall prevention recommendations, including home modification strategies and tailored exercise programs. This work advances digital health interventions for aging populations in Southeast Asian contexts by delivering a validated, scalable, and practical tool for fall prevention.

2. Materials and Methods

2.1. Research Design

This study aimed to develop a mobile application enabling older adults to self-assess their fall risk. This mixed-methods study comprised quantitative assessments of test–retest reliability and construct validity and qualitative evaluations of usability, acceptability, and user satisfaction.

2.2. Population, Inclusion, and Exclusion Criteria

The target population included 2 groups as follows:

(1) A total of 30 healthcare professionals, including 2 doctors, 10 physical therapists, 5 occupational therapists, 5 nurses, 3 public health technical officers, and 5 village health volunteers, all of whom had more than five years of professional experience in their respective fields.

(2) The study population consisted of 3569 older adults aged 60 and above, residing in Thasala District, Nakhon Si Thammarat Province. The inclusion criteria were living in their own residence and proficient in Thai, with access to the Internet. Those who were unable to do everyday activities and those who had dementia were excluded. Daily functional ability was assessed using the Barthel Index of Activities of Daily Living. A score of 4 or below (out of 20) indicated total dependence and was used as an exclusion criterion. Cognitive screening was performed using the Mini-Mental State Examination (MMSE-Thai 2002). Participants were excluded if their scores indicated cognitive impairment, defined as follows: a score of $\leq$14 out of 23 for those with no formal education; $\leq$17 out of 23 for those with education up to 7th grade; and $\leq$22 out of 23 for those with education beyond 8th grade.

2.3. Subject and Sample Size

Older adults were recruited to validate the application's construct validity, specifically examining convergent validity with the TUG test, a widely used screening tool for mobility and fall risk assessment in older adults. The TUG test measures the time taken for an individual to stand from a chair, walk three meters, turn around, return, and sit down, with longer completion times indicating higher fall risk [22]. The sample size was calculated using G*Power version 3.1 [23], based on a bivariate normal model for correlation analysis with $\alpha = 0.05$, power = 0.80, and expected correlation coefficient ($\rho H1$) = 0.30, yielding a required sample of 67 participants.

2.4. Application Development and System Architecture

The mobile application was developed using modular, cloud-based architecture to enhance scalability, reliability, and accessibility for older adults. The system architecture includes three primary layers: (1) a user interface layer providing intuitive interaction with adjustable font size and gesture-based navigation; (2) an application logic layer manag-

ing user input, form processing, risk scoring algorithms based on the Stay Independent Brochure (SIB) and Thai-HFHAT, and personalized feedback generation; and (3) a cloud-based backend handling data storage, synchronization, and analytics. All data are securely stored on Filebase using decentralized storage with encryption at rest and in transit. The application supports offline data collection with background synchronization when internet connectivity becomes available, ensuring accessibility in remote areas. The architecture is optimized for Android smartphones and tablets commonly used by older Thai adults. Figure 1 presents a simplified overview of the system architecture.

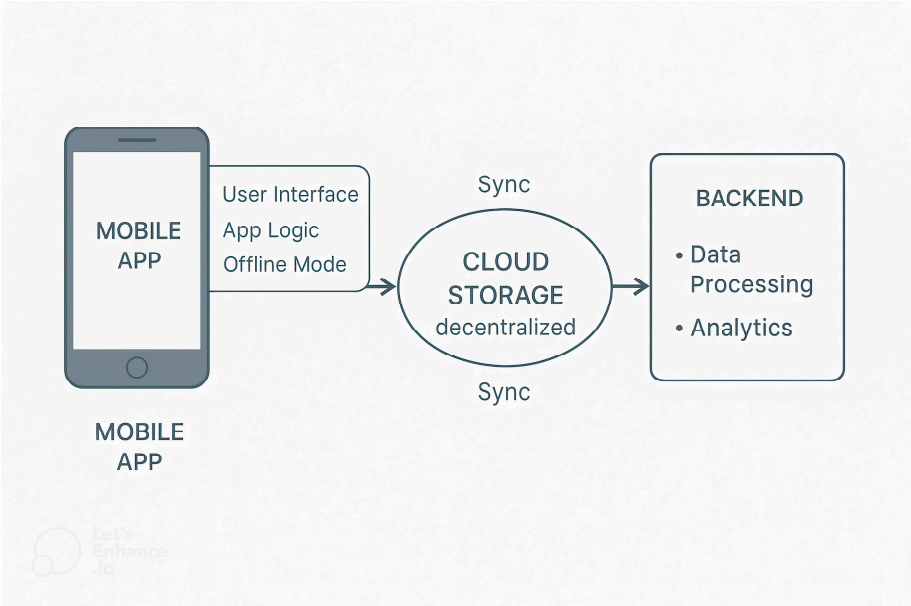


Figure 1. Working process of the application.

To ensure data security and confidentiality, particularly for personally identifiable information (PII), the application implements robust data protection mechanisms aligned with secure cloud storage best practices. Data stored on Filebase, a decentralized object storage service, is protected through encryption both at rest and in transit. At-rest encryption prevents unauthorized access to stored data even in cases of server compromise, while in-transit data are secured using HTTPS (TLS/SSL) protocols to prevent interception during transmission. The system implements strict access control policies, including robust authentication processes and role-based authorization to manage permissions. These integrated security measures safeguard sensitive user data throughout storage and transmission cycles, supporting compliance with modern data privacy standards and reinforcing user trust.

The application collects demographic information such as gender, age, marital status, address, and telephone number. It also integrates the 12-item Thai-version SIB and 44-item Thai-HFHAT to comprehensively assess both intrinsic and extrinsic fall risk factors. Upon completion of the assessment, the application generates a fall risk report and provides tailored self-management resources, including fall prevention exercise programs and instructional videos demonstrating home environments free of fall hazards. Figure 2 illustrates the overall user flow.

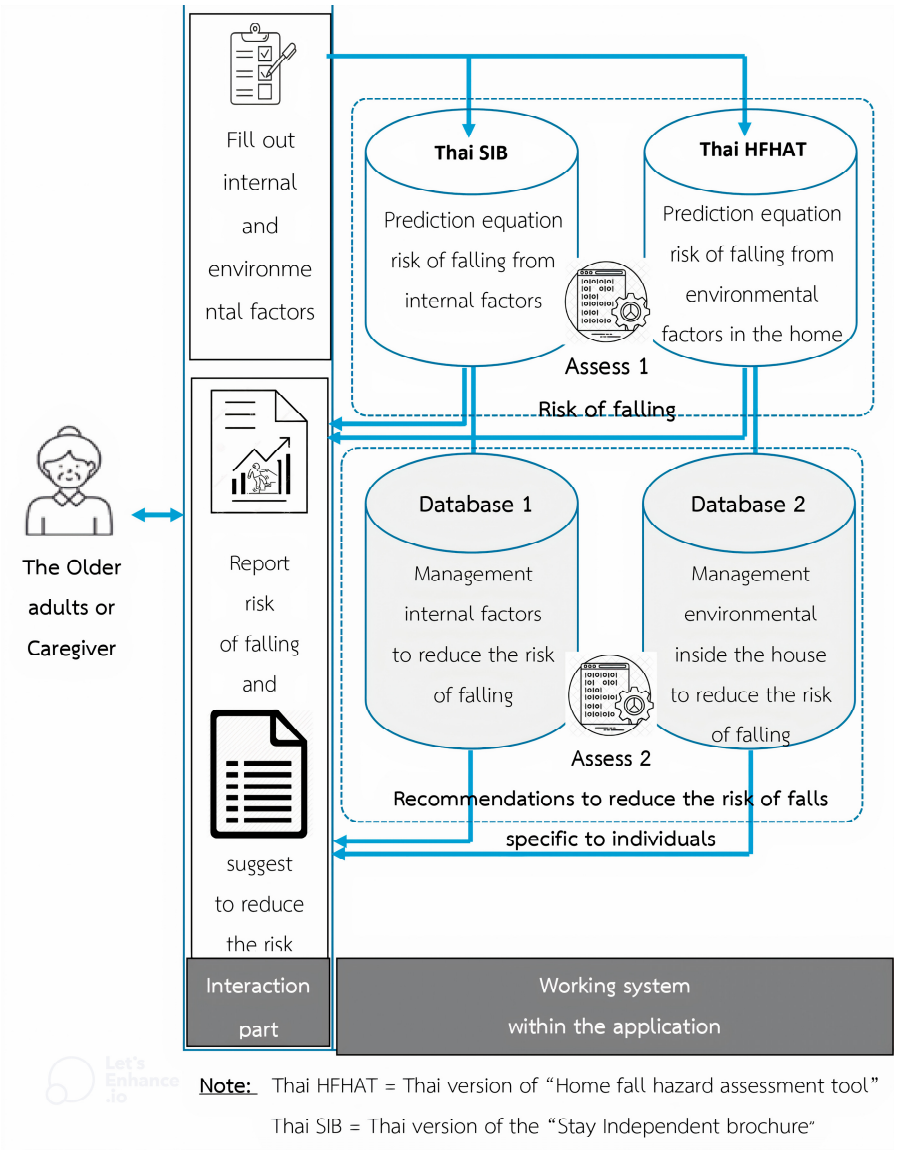


Figure 2. User flow diagram.

2.5. Outcome and Tools

Outcomes	**Detail, Tools, and Measure Method**
Health Professional outcomes	
Ease of Use	Users can access the app easily, not complicated.
Reliability	Consistency of the app operation under various conditions.
Response Times	How fast the response time of the app from the user request to the response time.
Ease of learning	Users can easily learn how to assess falls risk and how to solve them.
Satisfaction	Users evaluate the overall satisfaction of the app.

End-user outcomes	
The occurrence of overall and indoor fall events within the past year	Falls and the details of any falls from the past year are collected. Data included the fall place, circumstances of the fall, injury, and treatment. Participants are interviewed by researchers.
The score from the 44-question Thai-HFHAT	Participants' indoor home environments are evaluated using a 44-item checklist.
The score from the Stay Independent Brochure (SIB)	Participants assessed themselves using the SIB checklist.
Time Up and Go test (TUG)	Used to assess the risk of falls. Participants are evaluated by researchers.

2.6. Data Collection

This study addressed the research objectives of reducing falls and promoting fall-prevention behaviors among older adults through an application that provides a comprehensive assessment of intrinsic risk factors and home hazard modification education to increase environmental awareness. All procedures involving human participants complied with the ethical standards of the Walailak University institutional research committee (IRB reference no. WUEC-23-013-01) and adhered rigorously to the ethical principles outlined in the Declaration of Helsinki. These measures ensured the protection of participants' rights, safety, and well-being throughout the research process. All participants provided written informed consent prior to enrollment.

The study was conducted in two distinct phases: Phase I focused on application development and evaluation of usability metrics (ease of use, reliability, response times, learnability, and user satisfaction) with healthcare professionals as evaluators. Phase II involved older adult participants who validated the application through comparison with the TUG test and correlation with fall history data.

2.6.1. Phase I

The initial phase focused on application development and usability evaluation by 30 healthcare professionals. Although older adults represent the intended end-users, healthcare professionals were purposefully selected for initial usability testing due to their clinical expertise and familiarity with digital health technologies. This approach leveraged their professional insights to assess technical performance, user interface design, content clarity, and potential for integration into clinical practice, ensuring the application met both functional and clinical standards before proceeding to older adult testing. Participants were instructed to download the application and use it during their routine work over a two-week period. Usability evaluation employed a mixed-methods questionnaire featuring both closed and open-ended questions designed to assess five key domains: ease of use, system reliability, response times, learnability, and overall user satisfaction. Based on these evaluations, targeted modifications were implemented to optimize the application's usability and clinical appropriateness for the target population.

2.6.2. Phase II

In the second phase, the application was validated with 67 older adult participants to analyze validity and test–retest reliability. Participants completed demographic questionnaires and both assessment tools (44-question Thai-HFHAT and Thai-version SIB) using the application on two separate occasions with a one-week interval between assessments. Data from these repeated measurements were used to calculate the Intraclass Correlation Coefficient (ICC) for test–retest reliability. Convergent validity was evaluated by researchers through analysis of participants' fall history details from the previous year and perfor-

mance on the TUG test. Before the assessment, all older adult participants attended a brief orientation session conducted by trained researchers. During this session, participants were provided with verbal instructions and a live demonstration of how to use the mobile application step-by-step. The key features of the app, including how to select answers, navigate between sections, and submit the assessment, were explained using a sample device. Participants were also allowed to practice using the app under supervision to ensure comprehension and confidence prior to independent use. Assistance was available throughout the assessment if participants required further clarification. The development and evaluation process included several stages: initial design, expert usability evaluation, iterative improvements, field testing with older adults, and correlation analysis between assessment results and fall-related outcomes are shown in the following Figure 3.

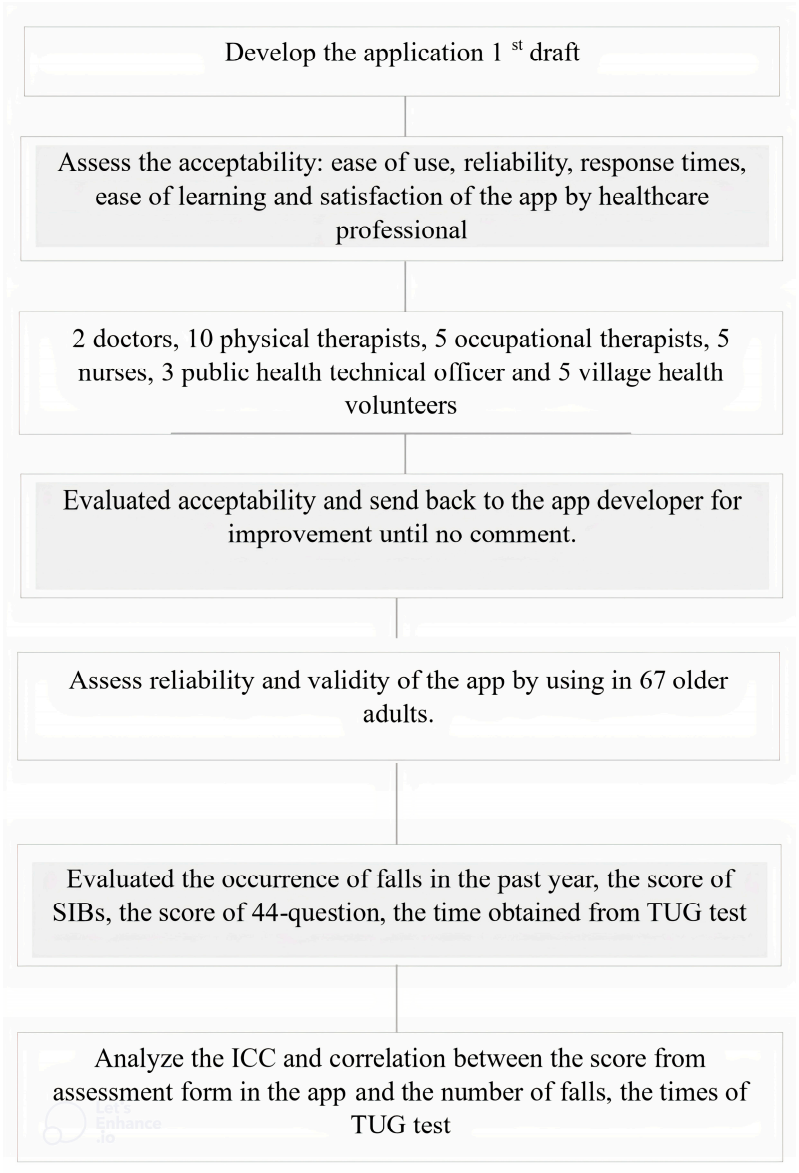


Figure 3. Flowchart of the development and evaluation process of the fall-risk screening mobile application.

2.7. Statistical and Data Analysis

Data were analyzed using both quantitative and qualitative methods to meet the study objectives. The statistical analysis of the data was carried out using the IBM SPSS Statistics v. 25.0 (IBM, Armonk, NY, USA). The following procedures were applied:

(1) The quantitative data were analyzed using descriptive statistics, reporting the result as frequency and percentage.
(2) The qualitative data were analyzed from open questions using thematic analysis. The qualitative data were read, re-read, then coded and collated under the items related to acceptability: ease of use, reliability, response times, ease of learning, and satisfaction with the app. A second researcher confirmed the coding.
(3) The test–retest reliability was analyzed using statistics Intraclass Correlation Coefficient model 3, 1 ($ICC_{3,1}$). Reliability was interpreted according to standard criteria, with ICC values ≥ 0.75 indicating good reliability.
(4) The correlation between the number of falls in the past year and the time from the TUG test was analyzed with the score from SIB (Thai-version) and the score from the 44-question Thai-HFHAT. Prior to correlation analysis, the normality of continuous data was assessed using the Shapiro–Wilk test. Since the data did not meet normal distribution assumptions, non-parametric methods were applied. Spearman's rank correlation coefficient was used to examine the association between the number of falls in the past year, TUG test time, and scores from the SIB (Thai-version) and 44-item Thai-HFHAT. A significance level (α) of 0.05 was applied, and p-values < 0.05 were considered statistically significant.

3. Results

3.1. Phase 1: Application Development

The application's usability was evaluated by 30 healthcare professionals. They were provided with instructions to download the app onto their devices and were asked to use it over a two-week period as part of their routine professional activities. The survey was based on an online questionnaire that included both closed- and open-ended questions designed to assess ease of use, reliability, response times, ease of learning, and overall satisfaction with the application.

3.1.1. The Characteristics of Healthcare Professionals

This project included 30 healthcare professionals, and the demographic characteristics of all participants, including two doctors, 10 physical therapists, five occupational therapists, five nurses, three public health technical officers, and five village health volunteers are shown in Table 1.

Table 1. Demographic characteristics of 30 Health professionals.

Health Professionals (n)	Gender (Female %)	Age (mean ± SD)	Year of Service (mean ± SD)
Doctors (2)	50	41.50 ± 4.90	7.00 ± 1.41
Physical therapists (10)	50	31.90 ± 4.01	7.50 ± 3.92
Occupational therapists (5)	80	32.40 ± 5.50	7.80 ± 2.58
Nurse (5)	100	38.40 ± 11.01	11.40 ± 7.20
Public health technical officers (3)	100	29.67 ± 2.51	5.67 ± 2.52
Village health volunteers (5)	60	54.80 ± 11.08	12.40 ± 5.59

3.1.2. System Usability Evaluation

Healthcare professionals rated the app using a modified System Usability Scale (SUS) and Technology Acceptance Model (TAM). The app scored 85.2 on the SUS (above the 68-industry benchmark for usability) and received high ratings in Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) from TAM evaluations.

3.1.3. Performance Analytics and User Behavior

Using backend analytics, key trends in user engagement were observed as follows:

The average time per assessment was 7.8 min. Completion rates were 92% for healthcare professionals and 89% for older adults. The error rate was less than 1%, indicating intuitive navigation.

3.1.4. Health Professional Satisfaction and Suggestion

The data in Table 2 show that most healthcare professionals strongly agreed or agreed that the application is easy to use, with 80–90% of respondents rating items in the highest two categories (4 or 5). In particular, the clarity of question arrangement and the appropriateness of the format were highly rated, indicating that the app's design is accessible. Furthermore, the majority of participants reported satisfaction with response times and ease of learning. However, a slightly lower score on item 1.2—regarding older adults using the app independently—suggests that while the interface is clear, some older users may still need assistance. This highlights the importance of supplementary features, such as audio guidance, to enhance usability.

Table 2. The health professional outcome.

Items	Number of Health Professionals (%)				
	5	**4**	**3**	**2**	**1**
(1) Ease of Use					
1.1 The application process is easy to use	26.67	53.33	20.00	0	0
1.2 Older adults can use the application on their own	13.33	50.00	36.67	0	0
1.3 Arrangement of questions is appropriate	53.33	40.00	6.67	0	0
1.4 The font size is appropriate for the elderly	40.00	32.50	27.50	0	0
1.5 The format of the application is appropriate	43.33	43.33	13.34	0	0
(2) Reliability					
2.1 Applications can be used to comprehensively assess the environment inside and around the home, regardless of variations in housing characteristics	56.67	33.33	10.00	0	0
(3) Response times					
3.1 Applications can display or respond after use within an acceptable time	60.00	36.67	3.33	0	0
(4) Ease of learning					
4.1 Older adults can easily learn to use it	20.00	63.33	16.67	0	0
(5) Overall satisfaction	43.33	50.00	6.67	0	0

The suggestions from Health professionals

(1) Some older adults may experience vision or reading difficulties, suggesting the need for an audio-assisted feature to read questions aloud.
(2) An example should be provided, or a video with images and audio should be included to guide users.
(3) There is a spelling error.

(4) Part 2 requires clearer instructions to guide users on the intended actions.
(5) The letters are too small, and the font color should be adjusted to be different from the background.

3.2. Phase 2: Applying Application to Older Adults

This phase involved older adult participants examining the reliability and validity of the application. Sixty-seven participants completed demographic questionnaires and used the app to assess the 44-question Thai-HFHAT and the SIB (Thai-version) twice. Meanwhile, researchers collected data on fall occurrences in the past year and TUG test performance. The demographic characteristics of participants are shown in Table 3.

Table 3. Demographic characteristics of 67 older adults.

Demographic Characteristics	Non Falling (n = 43)	Falling (n = 24)	*p*-Value
	n (%)	n (%)	
Age (years)			
Mean ± SD	67.98 ± 6.09	68.79 ± 5.98	0.554
Min–Max	60–90	59–80	
Gender			
Male	13 (30.23)	5 (20.83)	0.405
Female	30 (69.77)	19 (79.17)	
BMI (kg/m^2)			
Mean ± SD	25.13 ± 3.63	24.32 ± 2.74	0.122
Min–Max	17.71–32.46	19.82–29.49	
Educations Level			
Primary education	18 (41.86)	13 (54.17)	0.471
Above primary education	25 (58.14)	11 (45.83)	
Marital Status			
Single	5 (11.63)	2 (8.34)	0.116
Married/Living Together	32 (74.42)	11 (45.83)	
Divorced/Separated/Widowed	6 (13.95)	11 (45.83)	
Occupation			
Unemployed/Housewife	12 (27.91)	2 (8.34)	0.261
Trade/Laborer	10 (23.25)	3 (12.50)	
Retired Government Official	7 (16.28)	5 (20.83)	
Farmer	14 (32.56)	14 (58.33)	
Congenital disease			
No chronic disease	5 (11.63)	2 (8.34)	0.867
Diabetes	12 (27.90)	6 (25.00)	
Hypertension	20 (46.52)	9 (37.50)	
High blood cholesterol	4 (9.30)	4 (16.66)	
Others (e.g., heart disease, gout, rheumatoid arthritis	2 (4.65)	3 (12.50)	
Number of falling			
Mean ± SD		1.46 ± 0.93	
Min–Max		1–5	
1 times		17 (70.83)	
2 times		5 (20.83)	
3 times		1 (4.17)	
5 times		1 (4.17)	

Table 3 indicates that the demographic characteristics such as age, gender, BMI, and education level did not significantly differ between fallers and non-fallers ($p > 0.05$). However, a trend was observed in marital status and occupation, where a higher proportion of fallers were widowed or farmers. These trends, though not statistically significant, suggest potential social and lifestyle factors associated with fall risk, which may warrant further investigation in larger samples.

After participants completed the home hazard assessment and SIB using the app on two occasions with a one-week interval, the intraclass correlation coefficient (ICC) of the score from SIB Score (Thai-version) was 0.80 (95% CI: 0.70–0.87), with the mean (SD) of the first test being 2.51 (1.86) and the second test was 2.03 (1.84). The intraclass correlation coefficient (ICC) of the score from the 44-question Thai-HFHAT was 0.77 (95% CI: 0.66–0.86), with the mean (SD) of the first test being 5.40 (4.72) and the second test was 3.72 (3.10) that are shown in Figure 4.

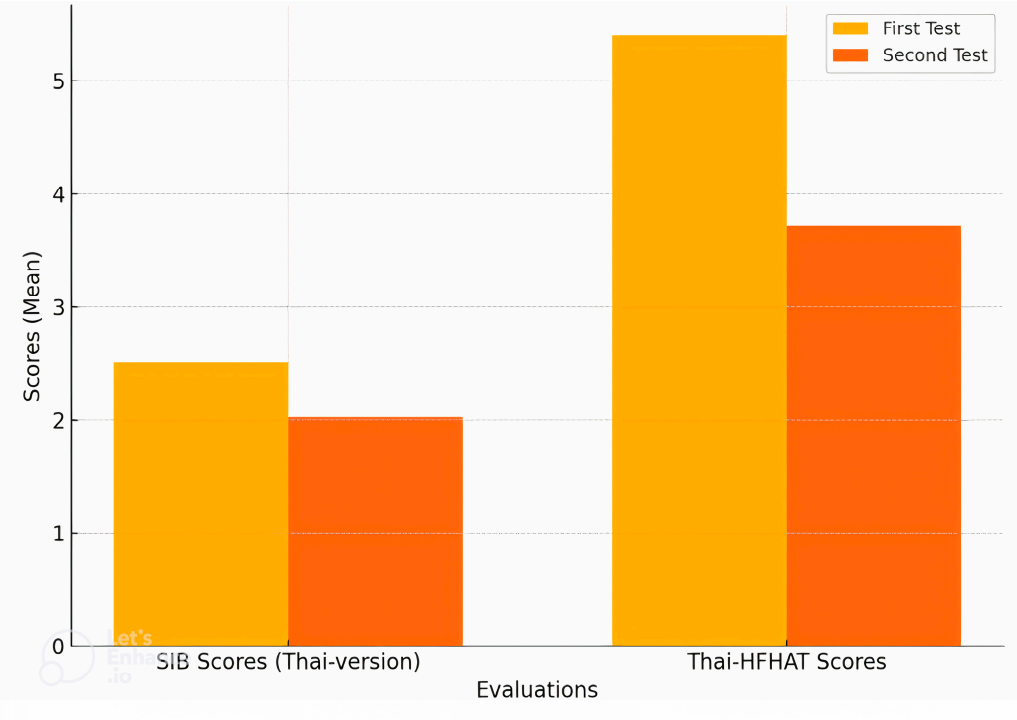


Figure 4. Comparison of average scores from two evaluation sessions.

The correlation between the number of falls in the past year and scores from two fall-risk screening tools: the Stay Independent Brochure (SIB) and the 44-question Thai-HFHAT. The data indicates a significant positive correlation for both tools. Specifically, the correlation coefficient for the SIB score is 0.657 ($p < 0.001$), while the Thai-HFHAT score has a higher correlation coefficient of 0.709 ($p < 0.001$). These results suggest that higher scores on both assessments are strongly associated with a greater number of falls among older adults, underscoring the tools' predictive validity in identifying individuals at risk of falling, as shown in Table 4. This finding supports the predictive validity of both tools and highlights their usefulness in identifying individuals at an increased risk of falling into a community setting.

Table 4. The correlation between the number of falls with the score from SIB (Thai-version) and the score from the 44-question Thai-HFHAT.

Variable	Correlation Coefficient	*p*-Value
SIB Score (Thai-version)	0.657	<0.001
44-question Thai-HFHAT Score	0.709	<0.001

The Spearman's rank correlation was performed, $p < 0.05$.

The relationship between the TUG test times and the scores from the SIB and Thai-HFHAT screening tools. The TUG test times correlate significantly with both the SIB score (correlation coefficient = 0.656, $p < 0.001$) and the Thai-HFHAT score (correlation coefficient = 0.632, $p < 0.001$). These findings highlight that longer TUG test times, indicating decreased mobility and higher fall risk, are associated with increased scores on both fall-risk assessments, reinforcing the tools' effectiveness in evaluating mobility-related fall risk factors, as shown in Table 5.

Table 5. The correlation between the time obtained from the TUG test with the score from SIB (Thai-version) and the score from the 44-question Thai-HFHAT.

Variable	Correlation Coefficient	*p*-Value
SIB Score (Thai-version)	0.656	<0.001
44-question Thai-HFHAT Score	0.632	<0.001

The Spearman's rank correlation was performed, $p < 0.05$.

4. Discussion

This study aimed to develop and evaluate a mobile application for fall-risk screening among older adults by integrating two validated tools—SIB and Thai-HFHAT—into a single digital platform. We have emphasized the innovation in mobile application development rather than focusing solely on the assessment tools themselves. The novelty of our work lies in the integration of two validated tools (SIB and Thai-HFHAT) into a single, user-friendly mobile platform specifically designed for community-dwelling older adults in Thailand. This integration allows for comprehensive screening of both intrinsic and extrinsic fall risk factors in a culturally and contextually relevant format [1]. In terms of technical and design contributions, the application was developed using a user-centered design approach, incorporating features that address common accessibility challenges among older adults—such as dynamic font sizing, gesture-based navigation, and simplified interface layout [24]. The app is compatible with both smartphones and tablets, increasing its adaptability in real-world settings. The cloud-based backend supports secure data storage and synchronization, ensuring that information remains accessible across devices and sessions. Most importantly, the app provides immediate, personalized feedback and practical fall prevention recommendations tailored to each user's risk profile, thereby enhancing the self-management potential of older adults [3]. Taken together, this application functions not merely as a data collection tool but as a digitally enabled, preventive health intervention. It reflects the growing importance of mobile health technologies in aging societies, particularly in low- and middle-income countries (LMICs), where access to routine fall-risk screening is often limited [1,25]. By addressing both usability and clinical utility, our application offers a scalable, validated, and context-specific solution to support fall prevention efforts at the community level.

The initial phase of this study aimed to assess the usability, reliability, and user satisfaction of a newly developed application among a diverse group of healthcare professionals, including physical therapists, doctors, occupational therapists, nurses, public health technical officers, and village health volunteers, all of whom had over five years of professional

experience. The feedback obtained from these professionals provides crucial insights into the app's effectiveness and areas for improvement. Regarding usability, the System Usability Scale (SUS) score of 85.2, reported by healthcare professionals in Phase 1, indicates excellent usability. This score notably exceeds the typical usability ratings for mHealth applications targeting older populations, which usually range from 70 to 80 [24]. Compared to European mHealth initiatives such as Fall Sensing and Prevent IT, which focus either on wearable integration or clinician-centered interfaces, our app demonstrated favorable usability within a Southeast Asian population using a culturally tailored approach.

The results from Table 2 demonstrate that the majority of healthcare professionals (80% or more) found the application easy to use, with positive ratings for the app's layout, font size, and overall format. This finding aligns with existing research indicating that ease of use is a critical determinant of technology adoption in healthcare settings [26]. Despite this, certain areas, such as font readability and the organization of content, received constructive feedback, highlighting the need to optimize these aspects for improved accessibility for older adults.

In terms of reliability, a substantial 90% of respondents agreed that the application could assess various environmental conditions reliably, regardless of house characteristics. Furthermore, 96.67% of professionals indicated satisfaction with the app's response times, suggesting that it meets the necessary standards for practical use in clinical environments. This is consistent with studies showing that response time and reliability are essential for health applications intended for routine use [27].

Overall satisfaction with the app was high, with 93.33% of participants expressing positive feedback. The suggestions from healthcare professionals indicated the need for additional features, such as voice-guided prompts, to accommodate elderly users who may have vision impairments. This recommendation is supported by research advocating adaptive features in health technologies to address the sensory limitations of older adults [28]. The recommendations underscore the importance of ongoing updates to ensure the app's effectiveness in real-world applications and its alignment with user needs. However, some healthcare professionals recommended modifications to improve the app's accessibility for older adults, such as incorporating larger font sizes and adding audio guidance. These suggestions underscore the importance of tailoring digital health tools to meet the specific needs of end-users, especially those with visual or auditory limitations. Future iterations of the app could address these adjustments to enhance accessibility, ensuring that older adults can easily navigate the tool independently. Implementing these improvements may not only increase user satisfaction but also broaden the app's reach in community health settings, where it could play a vital role in fall prevention efforts.

The second phase of this study aimed to evaluate the test–retest reliability of the SIB Score (Thai-version) and the 44-question Thai-HFHAT, both administered through a mobile application. The results demonstrated good to excellent reliability, as evidenced by intraclass correlation coefficients (ICCs) of 0.77 and 0.80, respectively. These values are comparable to earlier reports, such as those by Yardley et al., who developed and validated self-assessment tools for fall risk with strong psychometric properties [25]. Similarly, studies validating the original Thai-HFHAT in community settings have reported moderate to good reliability, supporting the consistency of our findings [29]. These findings suggest that both assessment tools exhibit stability over time when used to evaluate home hazards and balance performance [30].

The ICC of 0.80 for the SIB Score (Thai-version) indicates that this tool provides consistent evaluations of balance impairments, even across repeated measures. The observed reduction in mean scores from the first to the second test (2.51 to 2.03) could reflect a phenomenon known as "reactivity", where participants make behavioral or environmental

changes after an initial assessment, resulting in improved subsequent scores [31]. This suggests that the SIB assessment may serve not only as a reliable measure but also as an intervention tool that raises awareness and prompts self-directed improvements in balance-related behaviors.

Similarly, the ICC of 0.77 for the Thai-HFHAT aligns with prior studies' moderate to good reliability, which is comparable to findings in other culturally adapted versions of the tool [32]. The substantial decrease in mean scores from the first test (5.40) to the second test (3.72) highlights the potential for participants to modify their home environment based on feedback from the first evaluation. This reduction underscores the dual utility of the Thai-HFHAT in assessing hazards and facilitating preventive actions to reduce fall risks.

The findings of convergent validity in this study demonstrate a significant correlation between fall occurrences and the scores obtained from the Stay Independent Brochure (SIB) and the Thai-HFHAT, as evidenced by Spearman's rank correlation results. Specifically, the positive correlation coefficients (SIB: 0.657, Thai-HFHAT: 0.709) with p-values below 0.001 indicate that higher scores on these assessment tools are strongly associated with an increased risk of falls among older adults [9,10]. This relationship underscores the value of both tools in effectively identifying individuals at heightened risk due to intrinsic and environmental factors. The strong association found here supports the validity of these assessment tools as reliable predictors of fall risk, suggesting that they could be integral to preventive strategies, especially in community and home-based care settings where timely identification of risk factors is crucial. These results align with previous research and reinforce the importance of comprehensive fall-risk assessments that consider both personal and environmental hazards in fall prevention programs [5,6,33].

The results from the TUG test further validate the app's effectiveness as a fall-risk screening tool for older adults. The significant correlations between TUG test times and both SIB (0.656, $p < 0.001$) and Thai-HFHAT (0.632, $p < 0.001$) scores highlight that users who obtained higher scores on these assessments also demonstrated longer completion times on the TUG test, a well-established indicator of fall risk [22,34]. This finding emphasizes that the app can accurately reflect functional mobility impairments, which are crucial predictors of fall likelihood. By integrating the SIB and Thai-HFHAT assessments with TUG test validation, the app provides a comprehensive approach to fall-risk screening that is both accessible and clinically relevant [9,10]. This synergy between the app's internal assessments and the TUG test outcomes suggests that the app could serve as a reliable, user-friendly tool for routine screening and potentially empower older adults and caregivers to recognize and address fall risks proactively in community and home environments.

The information offered by e-Health interventions has been customized using computer-tailored technology, with the primary purpose of disease prevention [35–37]. This intervention technique provides computer-generated content, as well as home modification suggestions, based on the content of the 44-question Thai-HFHAT. It is suggested that to attract and maintain user attention, increase engagement, and improve comprehension, digital content must be tailored and interactive [38]. Several studies support the validity and reliability of the SIB and Thai-HFHAT tools in assessing fall risk, showing consistency with their psychometric properties and effectiveness as screening instruments. For instance, Loonlawong et al. (2019) examined the Stay Independent Brochure (SIB) in a Thai elderly population, reporting high content validity and excellent inter-rater reliability with an Intraclass Correlation Coefficient (ICC) of over 0.80) [9]. The SIB also demonstrated significant convergent validity with established physical assessments like the TUG and Berg Balance Scale (BBS), reinforcing its role as a reliable tool for identifying intrinsic fall risks [9]. Similarly, the Thai-HFHAT was validated by Lektip et al. (2020), who confirmed its predictive accuracy with an Area Under the Receiver Operating Characteristic (AUROC)

curve of 0.897, along with strong sensitivity (0.93) and specificity (0.72) [10]. These studies collectively underscore the effectiveness of both the SIB and Thai-HFHAT tools in identifying fall risk factors within Thai elderly populations, supporting their integration into community health initiatives focused on fall prevention.

This study presents several strengths that enhance its relevance to fall-risk assessment and prevention in older adults. First, the developed mobile application demonstrated high usability and user satisfaction among both healthcare professionals and community-dwelling older adults. The novelty of this application lies not in data collection alone but in the integration of two validated tools—the Stay Independent Brochure (SIB) and the Thai Home Falls Hazard Assessment Tool (Thai-HFHAT)—within a single platform capable of screening both intrinsic and extrinsic fall risk factors. This dual-focus approach addresses a major gap in existing mHealth solutions, which typically emphasize only intrinsic factors and are often designed for use by clinicians. Secondly, the dual-phase approach in this study ensures thorough validation from both healthcare professionals and end-users, strengthening the app's usability and reliability. In Phase I, 30 healthcare professionals evaluated the app over a two-week period, providing feedback on ease of use, reliability, response times, learning accessibility, and overall satisfaction. Their feedback not only confirmed the app's functional aspects but also highlighted areas for improvement, such as readability and instructions tailored to older adults. In Phase II, older adults directly used the app to assess their own fall risk, offering practical insights into how effectively the app performs in a real-world setting. This dual approach, addressing both expert and end-user perspectives, reinforces the app's feasibility for broader community and home-based implementations in fall prevention programs.

Finally, in addition to collecting data, the application provides immediate, personalized feedback based on the user's responses, including actionable fall prevention suggestions such as home modification strategies and tailored exercise recommendations. The design adopts a user-centered approach, with features such as adjustable font sizes, gesture-based navigation, and offline accessibility—making the tool highly suitable for older adults in resource-limited settings. Moreover, the app was empirically evaluated not only for usability but also for test–retest reliability, construct validity, and predictive validity through correlations with real-world fall incidents and TUG test results. These attributes collectively highlight the innovation and practical utility of the app as a reliable, scalable, and culturally relevant digital health tool for fall risk prevention among aging populations.

This study has several limitations that should be considered when interpreting the findings. First, the sample size may limit the generalizability of the results, particularly in representing the broader population of older adults in different regions. While the study included 67 older adult participants and 30 healthcare professionals, a larger sample size would provide a more diverse representation, accounting for variations in living environments, health conditions, and technological familiarity, which may influence the effectiveness and usability of the app. Another limitation is the potential for response bias from the healthcare professionals who assessed the app. Given their background and familiarity with fall risk factors and assessments, their evaluations of the app's ease of use, reliability, and effectiveness may have been influenced by prior knowledge. This could result in a more favorable assessment of the app compared to feedback from end-users without specialized knowledge in fall prevention. Future studies could address this by involving healthcare professionals less directly familiar with fall risk assessments to reduce potential bias and by ensuring a larger sample of end-users to further evaluate the app's usability in a real-world context.

The findings offer meaningful implications for clinical practice and digital fall-prevention strategies. By demonstrating significant correlations between fall risk and

both intrinsic and extrinsic factors, as assessed by the Stay Independent Brochure (SIB) and Thai-HFHAT, this app offers a streamlined, comprehensive approach to fall risk assessment. Integrating this digital tool into community health settings could simplify and enhance fall screening processes, allowing healthcare providers to quickly identify individuals at higher risk and implement targeted interventions. The app's digital format, with easy access on mobile devices, may also improve the scalability of fall prevention programs, making it possible to reach a larger number of older adults in diverse geographic areas.

To maximize the app's effectiveness, further refinement is recommended to enhance its user-friendliness, particularly for older adults with visual impairments. For instance, incorporating larger font sizes, clearer contrasts, and audio guidance for questionnaire items could significantly improve accessibility and usability for this population. Future research should focus on these design modifications and test the app's usability with a broader demographic of older adults, especially those with varying levels of digital literacy. Additionally, studies should evaluate the app's long-term impact on fall prevention outcomes, exploring how regular use of the tool influences fall rates and self-management behaviors over time. Furthermore, mobile applications should incorporate machine learning algorithms to enhance fall risk prediction based on user demographics and behavioral data. In addition, integration with wearable IoT devices (e.g., fall-detection sensors) and EHR systems would strengthen its application in clinical practice. To enhance the specificity of these directions, future studies could be structured as phased interventions. For example, one study could implement and test a version of the app equipped with audio-assisted navigation and large-font text, assessing its usability and effectiveness among older adults with visual or cognitive impairments using randomized controlled trials. Another study could deploy the app in rural or underserved communities to examine feasibility and adoption among those with low digital literacy. Moreover, longitudinal research over a 6–12-month period could track how sustained app usage impacts fall rates, environmental adjustments, and behavioral adherence to prevention strategies. For AI integration, machine learning models should be trained and validated using real-world usage data stratified by age, comorbidities, and living conditions. Pilot implementation of the app in primary care clinics with EHR interoperability could also evaluate clinical workflow integration and provider acceptance. These targeted directions will help advance the app into a more inclusive, intelligent, and effective digital health tool for fall prevention in diverse aging populations.

5. Conclusions

This study highlights the critical role of assessing both environmental and intrinsic risk factors in fall prevention among older adults. By integrating the Stay Independent Brochure (SIB) and the Thai-HFHAT into a single, user-friendly digital app, the study demonstrates how accessible technology can effectively support comprehensive fall risk screening. The strong correlations found between these assessment scores and fall occurrences reinforce the need for multifaceted screening tools that can address the diverse risk factors contributing to falls. Moreover, this study demonstrates how informatics-driven mobile applications can enhance fall-risk assessment through real-time analytics, user-centered design, and cloud-based data management. By leveraging digital health technologies, the app provides a scalable, cost-effective solution for fall prevention among older adults. Future research should explore AI-based fall prediction, interoperability with healthcare systems, and engagement strategies to maximize real-world impact.

Author Contributions: Conceptualization, N.W., C.L., W.J., C.K. and J.N.; Methodology, N.W., C.L., W.J., C.K. and J.N.; Formal analysis, V.S., C.L. and L.M.; Project administration, C.L.; Software, C.K.; Supervision, W.J.; Validation, J.N. and V.S.; Visualization, C.L. and W.J.; Writing—original draft preparation, N.W., V.S. and C.L.; Writing—review and editing, N.W., C.L., W.J., C.R., J.N., C.K., V.S. and L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work (Grant No. RGNS 65-227) was supported by the Office of the Permanent Secretary, Ministry of Higher Education, Science, Research and Innovation (OPSMHESI), Thailand Science Research and Innovation (TSRI), and Walailak University.

Institutional Review Board Statement: Walailak University (IRB reference no. WUEC-23-013-01).

Informed Consent Statement: All participants consented to participate in the research. Everyone signed the consent form to participate in the research.

Data Availability Statement: The data used to support the findings of this study are openly available in Figshare at https://figshare.com/s/e280c556445fde74282d (accessed on 1 December 2024), reference number 10.6084/m9.figshare.27935037.

Acknowledgments: The authors are thankful to Sikarin Punsawat for generating the application, and are thankful to all of the participants who participated in this study. The authors acknowledge the use of artificial intelligence (AI) software in the preparation of this manuscript. Specifically, ChatGPT version GPT-4o was utilized for language editing. The authors confirm that the use of this software adhered to ethical guidelines and was under their direct supervision. All interpretations and conclusions presented in the manuscript remain the sole responsibility of the authors.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

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