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# A stakeholder-based confirmatory factor analysis of a smartwatch innovation management model for holistic older adult health care in Thailand

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**Abstract:** Thailand's transition to a super-aged society requires innovative management frameworks to support technology-enabled healthcare for older adults. Smartwatches offer significant potential for continuous health monitoring. However, a validated management model suitable for Thailand's healthcare context remains underdeveloped. Therefore, this study developed and validated a second-order confirmatory factor analysis (CFA) of smartwatch innovation management factors for holistic older adult care, grounded in stakeholder perspectives. A cross-sectional survey was conducted with 260 stakeholders involved in a smartwatch-based elderly care pilot project in Thailand's northern Chiang Rai Province. Participants included physicians, nurses, village health volunteers, and caregivers. Data were collected using a five-point Likert-scale questionnaire comprising 13 observed variables across four proposed components. These included Health Data Management (HMS1), Holistic Health Integration (HMS2), Connection with Healthcare Services (HMS3), and Technology Design Suitability for Older Adults (HMS4). LISREL was used to conduct the CFA, which assessed construct validity. The second-order model demonstrated excellent fit ($\chi^2 = 2.54$, df = 6, p = 0.952, $\chi^2/df = 0.42$, RMSEA = 0.00, CFI = 0.99, GFI = 0.98). All first- and second-order factor loadings were statistically significant ($p < .01$). HMS4 ($\beta = 0.95$) and HMS3 ($\beta = 0.94$) emerged as the most influential dimensions. Construct reliability and convergent validity were confirmed (CR ≥ 0.75; AVE ≥ 0.50). The findings indicate that effective smartwatch innovation management for older adults must prioritize age-appropriate technology design and integration with formal healthcare systems. The validated framework provides policy and implementation guidance grounded in professional stakeholder assessment.
***Keywords:*** *Holistic health care, Innovation management, Senior citizens, Smartwatch, Thailand.*

## 1. Introduction

Thailand achieved an aged society status in 2023 when 20% of its population reached 60 years or older (Figure 1). The country will attain Super Aged Society status in 2026 when 28% of its population reaches this demographic [1]. The Thai government developed multiple essential policies together with strategic plans to manage this major demographic transformation. One of these is the 2nd National Plan for Older Adults (2022-2036), which articulates a vision of "Thai older adults having a good quality of life, dignity, and serving as a driving force for sustainable national development." The 20-Year National Strategy (2018-2037) also requires innovation and technology to improve an individual's quality of life while building a sustainable health system that drives national progress. The Thailand 4.0 policy supports social problem-solving through digital technology and innovation, which doctors use to deliver better healthcare services to an expanding, complex population [2].


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The population of Thailand in 2023 reached an estimated 66 million people. Of this total, 13 million belonged to the age group of 60 years and older. The increasing population of elderly people in society creates new difficulties for both social systems and medical treatment systems. The educational background of most senior citizens remains low, which creates significant difficulties for them when they try to find medical information and healthcare services [3]. Health issues become most important because aging makes people more vulnerable to developing chronic non-communicable diseases (NCDs), which include stroke, heart disease, diabetes, and dementia. These conditions result in a combined loss of healthy life years measured in disability-adjusted life years (DALYs), decreasing everyday functioning capabilities while increasing the need for family assistance [4, 5].

Fortunately, the existing problems are best addressed by smartwatch technology, which offers an effective solution to these needs (Figure 1). Smartwatches are wrist-worn devices that provide multimedia capabilities and instant data access via Bluetooth connections to smartphones [6, 7]. The combination of *Personal Emergency Response Systems* (PERS) together with fall detection and GPS tracking systems creates essential features that manufacturers have developed for elderly care needs [7, 8]. Moreover, mHealth (mobile health) uses mobile technology to deliver medical and public health services via patient health data monitoring systems that operate on mobile devices [9, 10]. Researchers have begun to define the essential elements that enable successful elderly care through smartwatch technology, according to recent studies. The implementation process requires robust Health Data Management, which entails collecting, securely storing, and analyzing health data effectively [11].

Furthermore, any mHealth system needs more than tracking capabilities; it must provide comprehensive support for Holistic Health Integration, which assesses physical activity, mental health, and social relationships [12]. The value of this information increases when the system provides direct access to healthcare services through its connections to hospitals, community health workers, and telemedicine platforms, creating an uninterrupted healthcare delivery system [13]. The success of these innovations depends on Technology Design Suitability for Older Adults, as products must meet user needs through easy operation and long-lasting performance, and require comprehensive user education to handle age-related changes and varying levels of digital proficiency [12-14].


**Figure 1.**
Conceptualized Smartwatch Design and Features for Older Adults in Thailand.
**Source:** The Authors and ChatGPT 5.2 Image Generator.

The successful implementation of smartwatch technology for holistic elderly care in Thailand requires more than mere components. The project requires a management framework that includes all essential components to be executed within its specific operational environment. The model needs to address the complete requirements of Thai older adults by including their social, cultural, and economic needs, as well as public policies, service delivery, and data management systems [15-17]. International research has studied various aspects of wearable health technology. However, there remains no established framework to manage these technologies in Thailand's specific context, which faces rapid population aging and a unique health system.

This study was therefore designed to address this gap. The main aims of the study were to investigate the essential elements that enable smartwatch innovation management to deliver comprehensive healthcare services for older adults in Thailand and to test the developed model's factor structure using Confirmatory Factor Analysis (CFA) on real-world data. A validated holistic management model (HMM) will establish a sustainable elderly care system, reducing health service access gaps and supporting Thailand's goal to become an exemplary elderly care model as it prepares to assume the ASEAN nation with the highest senior demographic.

## 2. Methods

### *2.1. Study Design*

A cross-sectional survey design was employed to develop and validate a second-order Confirmatory Factor Analysis (CFA) model of Smartwatch Innovation Management for Holistic Health Care among older adults in Thailand.

### *2.2. Population and Sample*

Thailand's northernmost province, Chiang Rai, served as a 2025 pilot area for implementing smartwatches in elderly care. The target population included stakeholders directly involved in the smartwatch-based elderly care initiative, such as physicians, nurses, village health volunteers, and caregivers.

Sample size was determined based on multivariate analysis guidelines recommending a minimum of 10–20 participants per observed variable [17]. With 13 observed variables, a minimum of 130–260 participants were required. The final sample included 260 respondents, satisfying the recommended criteria for CFA.

A multi-stage sampling approach was used. The province was first divided geographically, and four districts (Mae Fa Luang, Mueang, Chiang Saen, and Wiang Pao) were randomly selected. Within each district, participants were recruited using convenience sampling among professionals involved in the smartwatch trial.

### *2.3. Research Instrument*

A structured questionnaire was used to collect each participant's opinions. The survey consisted of two sections:

Section 1: Demographic characteristics (gender, age, education, professional role).

Section 2: Thirteen items measuring four latent constructs:

1. Health Data Management (HMS1)
2. Holistic Health Integration (HMS2)
3. Connection with Healthcare Services (HMS3)
4. Technology Design Suitability for Older Adults (HMS4)

Each survey item was ranked using a five-point Likert scale (1 = lowest, 5 = highest).

Content validity was assessed using the Index of Item-Objective Congruence (IOC), with values ranging from 0.80 to 1.00. Item discrimination indices ranged from 0.45 to 0.75. Internal consistency reliability (Cronbach's alpha) ranged from 0.89 to 0.90 across constructs.

### *2.4. Data Collection*

Data were collected from 260 participants following informed consent procedures. Participation was voluntary, and responses were anonymous.


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*2.5. Data Analysis*

Data were analyzed using descriptive statistics and Confirmatory Factor Analysis (CFA) with LISREL.

Model fit was evaluated using multiple indices [18-24]:

- Chi-square ($\chi^2$, $p \geq 0.05$)
- Relative Chi-square ($\chi^2/df \leq 2.00$)
- Root Mean Square Error of Approximation (RMSEA ≤ 0.05)
- Root Mean Square Residual (RMR ≤ 0.05)
- Goodness-of-Fit Index (GFI ≥ 0.90)
- Adjusted Goodness-of-Fit Index (AGFI ≥ 0.90)
- Comparative Fit Index (CFI ≥ 0.90)
- Normed Fit Index (NFI ≥ 0.90)

Construct reliability (CR ≥ 0.70) and Average Variance Extracted (AVE ≥ 0.50) were used to assess convergent validity.

*2.6. Ethical Considerations*

This study involved only non-vulnerable adults and anonymous, non-sensitive data. According to the National Research Council of Thailand [25], anonymous social and behavioral research that poses no physical or psychological risk does not require formal institutional ethics approval. Therefore, ethics review was not required. However, all participants provided an informed consent form (ICF) before participation.

## 3. Results

*3.1. Demographic Characteristics of the Sample*

Among the 260 participants, 51.15% were female and 45.00% male. The largest age group was 40–49 years (36.92%). Most respondents had an education below a bachelor's degree (66.92%). Village health volunteers constituted the largest professional group (50.38%), followed by nurses (26.93%), caregivers (16.93%), and physicians (5.76%) (Table 1).

**Table 1.**
Demographic Characteristics of the Sample (n=260).

| Characteristic | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Gender | Male | 117 | 45.00 |
| | Female | 133 | 51.15 |
| | Not Specified | 10 | 3.85 |
| Age (years) | ≤ 29 | 38 | 14.61 |
| | 30-39 | 71 | 27.30 |
| | 40-49 | 96 | 36.92 |
| | ≥ 50 | 55 | 21.17 |
| Education | < Bachelor's Degree | 174 | 66.92 |
| | Bachelor's Degree | 66 | 25.38 |
| | Master's Degree | 16 | 6.15 |
| | Doctoral Degree | 4 | 1.55 |
| Current Position | Physician | 15 | 5.76 |
| | Nurse | 70 | 26.93 |
| | Village Health Volunteer | 131 | 50.38 |
| | Caregiver | 44 | 16.93 |

*3.2. Descriptive Statistics of the Variables*

All four latent constructs demonstrated high mean scores (range = 4.36–4.42) (Table 2). Health Data Management recorded the highest mean (M = 4.42, SD = 0.37). Among observed variables, Data Accuracy showed the highest individual mean score (M = 4.49, SD = 0.40).

**Table 2.**
Descriptive Statistics of Latent and Observed Variables (n=260).

| Latent & Observed Variables | Mean | SD | Interpretation |
|---|---|---|---|
| Health Data Management (HMS1) | 4.42 | 0.37 | High |
| Data Accuracy (RCI1) | 4.49 | 0.40 | High |
| Data Security and Privacy (RCI2) | 4.42 | 0.39 | High |
| Service Provision (RCI3) | 4.43 | 0.43 | High |
| Analytical and Predictive Capability (RCI4) | 4.34 | 0.45 | High |
| Holistic Health Integration (HMS2) | 4.37 | 0.40 | High |
| Physical Health Tracking (FHM1) | 4.42 | 0.42 | High |
| Mental Health Care (FHM2) | 4.28 | 0.43 | High |
| Social Health Promotion (FHM3) | 4.41 | 0.42 | High |
| Connection with Healthcare Services (HMS3) | 4.36 | 0.43 | High |
| Connection with Hospitals (HNW1) | 4.42 | 0.45 | High |
| Connection with Community Health Units (HNW2) | 4.39 | 0.48 | High |
| Telemedicine Systems (HNW3) | 4.29 | 0.51 | High |
| Technology Design Suitability for Older Adults (HMS4) | 4.39 | 0.45 | High |
| Age-Friendly Usability (UFH1) | 4.14 | 0.74 | High |
| Durability and Reliability (UFH2) | 4.19 | 0.74 | High |
| Support and Training (UFH3) | 4.21 | 0.70 | High |

### *3.3. Confirmatory Factor Analysis (CFA)*

The empirical data showed strong alignment with the proposed Smartwatch Innovation Management for Holistic Health Care model among Older Adults in Thailand. The second-order CFA model demonstrated excellent fit with the empirical data:

- $\chi^2 = 2.54$
- df = 6
- p = 0.952
- $\chi^2/df = 0.42$
- RMSEA = 0.00
- RMR = 0.00
- GFI = 0.98
- AGFI = 0.98
- NFI = 0.99
- CFI = 0.99

All indices exceeded recommended thresholds, indicating strong construct validity. The low degrees of freedom (df = 6) may partially explain the exceptionally high fit statistics.

#### *3.3.1. First-Order Factor Loadings*

All observed variables loaded significantly on their respective latent constructs ($p < .01$). Standardized factor loadings ranged from 0.65 to 0.88, indicating satisfactory indicator reliability.

Construct reliability (CR) values ranged from 0.75 to 0.88, exceeding the 0.70 threshold. Average Variance Extracted (AVE) ranged from 0.51 to 0.72, confirming convergent validity.

#### *3.3.2. Second-Order Factor Loadings*

All four first-order constructs loaded significantly onto the higher-order construct, Smartwatch Innovation Management ($p < .01$).
Standardized loadings were:
Technology Design Suitability for Older Adults (HMS4): $\beta = 0.95$
Connection with Healthcare Services (HMS3): $\beta = 0.94$
Health Data Management (HMS1): $\beta = 0.88$
Holistic Health Integration (HMS2): $\beta = 0.85$

These results indicate that Technology Design Suitability and Healthcare Connectivity were the most influential dimensions of the overall model.

**Table 3.**
Results of First and Second Order CFA for the Smartwatch Innovation Management Model

| 2nd Order | 1st Order | Component Weights | | | | CR | AVE | Rank |
|---|---|---|---|---|---|---|---|---|
| | | $b_{sc}$ | SE | t | $R^2$ | | | |
| First Order CFA | | | | | | | | |
| HMS1 | RCI1 | 0.75** | 0.06 | 13.75 | 0.70 | 0.82 | 0.54 | 2 |
| | RCI2 | 0.80** | 0.06 | 14.30 | 0.72 | | | 1 |
| | RCI3 | 0.69** | 0.05 | 22.78 | 0.68 | | | 4 |
| | RCI4 | 0.70** | 0.05 | 25.36 | 0.70 | | | 3 |
| HMS2 | FHM1 | 0.76** | 0.07 | 13.98 | 0.70 | 0.75 | 0.51 | 1 |
| | FHM2 | 0.67** | 0.07 | 12.87 | 0.68 | | | 3 |
| | FHM3 | 0.70** | 0.07 | 11.80 | 0.69 | | | 2 |
| HMS3 | HNW1 | 0.88** | 0.05 | 24.42 | 0.77 | 0.83 | 0.63 | 1 |
| | HNW2 | 0.84** | 0.05 | 27.91 | 0.71 | | | 2 |
| | HNW3 | 0.65** | 0.04 | 21.25 | 0.62 | | | 3 |
| HMS4 | UFH1 | 0.87** | 0.03 | 22.74 | 0.72 | 0.88 | 0.72 | 1 |
| | UFH2 | 0.84** | 0.03 | 21.18 | 0.70 | | | 3 |
| | UFH3 | 0.85** | 0.04 | 21.24 | 0.71 | | | 2 |
| Second Order CFA | | | | | | | | |
| HMS | HMS1 | 0.88** | 0.07 | 24.28 | 0.77 | 0.82 | 0.94 | 3 |
| | HMS2 | 0.85** | 0.08 | 21.51 | 0.73 | | | 4 |
| | HMS3 | 0.94** | 0.06 | 26.17 | 0.87 | | | 2 |
| | HMS4 | 0.95** | 0.06 | 28.17 | 0.87 | | | 1 |
| Chi-Square= 2.54, df = 6, p = 0.952, $\chi^2$/df = 0.42, RMSEA = 0.00, RMR = 0.00, GFI = 0.98, AGFI = 0.98 | | | | | | | | |

**Note:** **p < .01.

**Table 4.**
Results of 1st and 2nd Order CFA for the Smartwatch Innovation Management Model.

| Second-Order Factor | First-Order Factor | bsc | SE | t | $R^2$ |
|---|---|---|---|---|---|
| Smartwatch Innovation Management (HMS) | | | | | |
| | Health Data Management (HMS1) | 0.88** | 0.07 | 24.28 | 0.77 |
| | Holistic Health Integration (HMS2) | 0.85** | 0.08 | 21.51 | 0.73 |
| | Connection with Healthcare Services (HMS3) | 0.94** | 0.06 | 26.17 | 0.87 |
| | Technology Design Suitability (HMS4) | 0.95** | 0.06 | 28.17 | 0.87 |

**Note:** **p < .01, bsc = standardized factor loadings. Model Fit Indices: $\chi^2$ = 2.54, df = 6, p = 0.952, $\chi^2$/df = 0.42, RMSEA = 0.00, RMR = 0.00, GFI = 0.98, AGFI = 0.98

Construct reliability (CR) for all components was above the 0.60 threshold, indicating high internal consistency (Figure 2). The average Variance extracted (AVE) for all components was above the 0.50 threshold, confirming convergent validity (Table 4).

**Table 5.**
The Model's Construct Reliability and Average Variance Extracted (AVE).

| Component | Construct Reliability (CR) | AVE |
|---|---|---|
| Health Data Management (HMS1) | 0.82 | 0.54 |
| Holistic Health Integration (HMS2) | 0.75 | 0.51 |
| Connection with Healthcare Services (HMS3) | 0.88 | 0.72 |
| Technology Design Suitability (HMS4) | 0.80 | 0.58 |

**Note:** All CR values exceeded 0.70, and all AVE values exceeded 0.50, confirming adequate reliability and convergent validity.

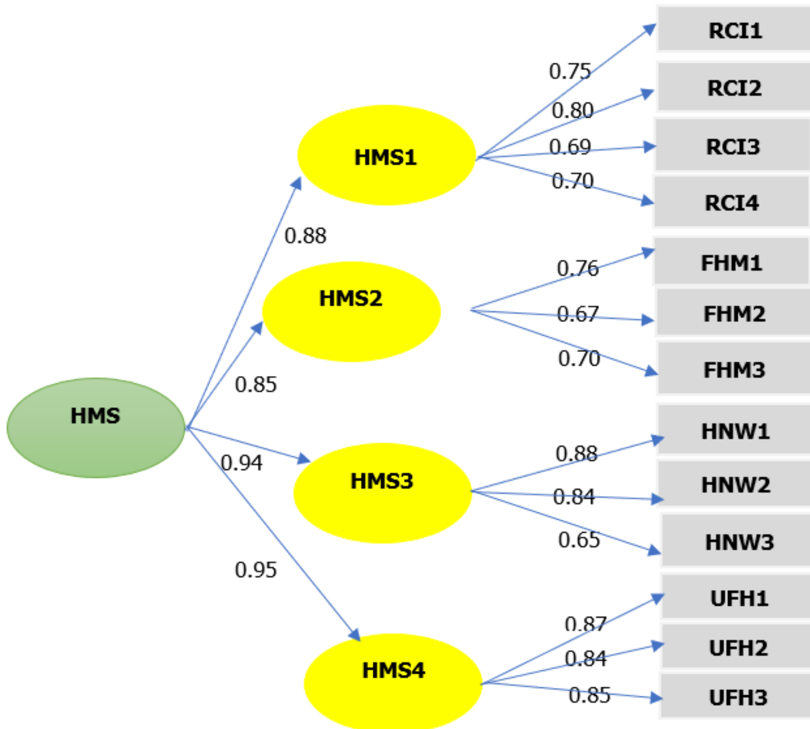


**Figure 2.**
The Final Second Order CFA Model for Smartwatch Innovation Management for Holistic Health Care among Older Adults in Thailand.
**Note:** Chi-Square= 2.54, df = 6, p = 0.952, $\chi^2$/df = 0.42, RMSEA = 0.00, RMR = 0.00, NFI = 0.99, CFI = 0.99, GFI = 0.98, AGFI = 0.98. The exceptionally high model fit may reflect the low degrees of freedom and parsimonious model structure. The path coefficients from HMS to HMS1-4 are: 0.88, 0.85, 0.94, and 0.95.

## 4. Discussion

This study developed and validated a second-order CFA of Smartwatch Innovation Management for Holistic Older Adult Care based on perceptions of healthcare stakeholders involved in a pilot implementation in Thailand. Instead of examining older adult end-user adoption, this research evaluated system-level readiness and management priorities from professionals responsible for implementation and service delivery. The findings provide empirical support for the proposed four-component framework.

The CFA demonstrated strong model fit and statistically significant factor loadings at both first- and second-order levels. Although the fit indices were exceptionally high, this may be partially attributable to the model's parsimonious structure and low degrees of freedom. Nonetheless, all constructs met recommended thresholds for reliability and convergent validity, supporting the structural integrity of the proposed framework (Figure 3).

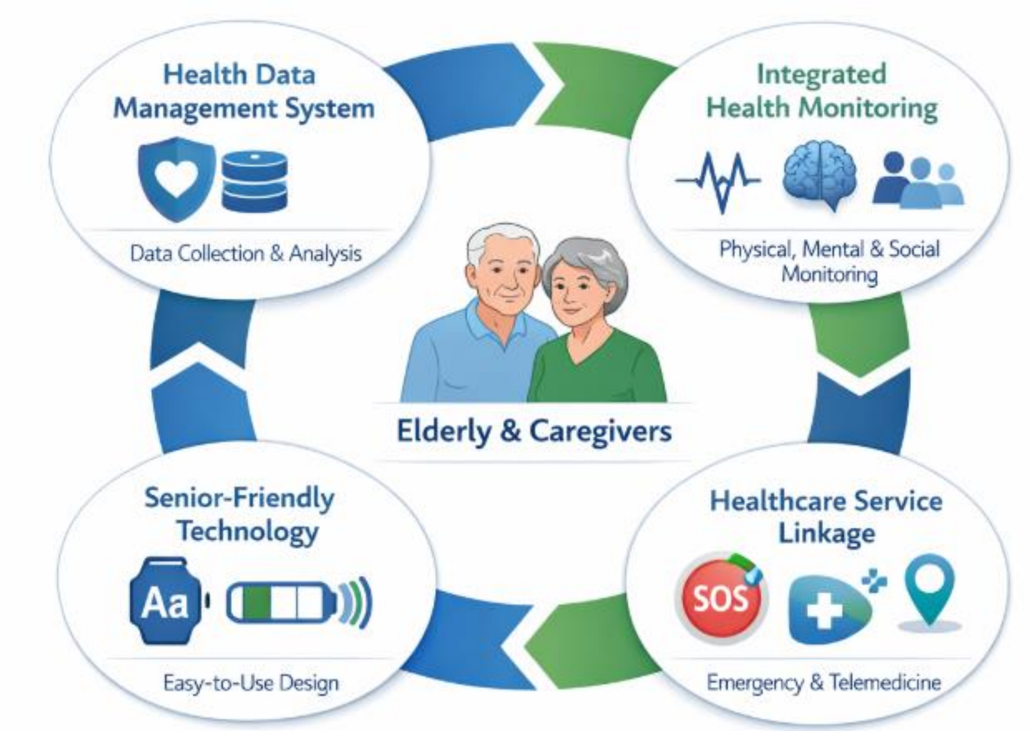


**Figure 3.**
Conceptualized Integrated Holistic Health Management Care for Older Adults in Thailand.
**Source:** The Authors and ChatGPT 5.2 Image Generator.

*4.1. Technology Design Suitability for Older Adults (HMS4)*

The results indicate that HMS4 (β = 0.95) was the most influential component of the higher-order construct. This finding aligns with prior research emphasizing age-appropriate usability, cognitive simplicity, and ergonomic design as critical determinants of successful technology implementation in aging populations [15, 26]. From a management perspective, stakeholders perceive that even well-integrated systems will fail if devices are not physically comfortable, visually accessible, and easy to operate. This underscores the importance of human-centered design principles in digital health innovation, particularly within aging societies [27].

*4.2. Connection with Healthcare Services (HMS3)*

The second strongest component, HMS3 (β = 0.94), reflects the perceived need to integrate wearable data into formal healthcare systems. Stakeholders emphasized interoperability with hospitals, community health units, and telemedicine systems. This aligns with integrated care models and digital health transformation frameworks, which emphasize that technology adoption must extend beyond device use to encompass seamless institutional integration [15]. In the Thai context, where village health volunteers play a central role in primary care delivery, connectivity between wearable devices and community-based health infrastructure appears especially critical [16].

*4.3. Health Data Management* (HMS1)

HMS1 (β = 0.88) emerged as the third-most influential dimension. This component captures issues of data accuracy, security, storage, and analytical capability [14, 28]. Given the sensitivity of health data and increasing concerns about digital privacy, robust governance mechanisms are essential to sustain stakeholder trust. The findings reinforce broader digital health literature, highlighting data integrity and cybersecurity as foundational to the success of wearable technology.

*4.4. Holistic Health Integration (HMS2)*

HMS2 showed the least weight (β = 0.85) among its four parts but maintained both statistical significance and essential value. The dimension represents a multi-dimensional health model that includes physical health, mental health, and social well-being elements. Stakeholders understand that wearable technologies need to advance from their current functions of counting steps and monitoring vital signs to delivering complete well-being support according to holistic care models and World Health Organization digital health principles [13].

## 5. Theoretical and Conceptual Implications

The research establishes an operational definition of "Smartwatch Innovation Management" through its second-order construct, which unites three technological, clinical, and system-based elements. The framework creates structural systems that healthcare ecosystems need to implement their operations through the integration of readiness and management functions. The distinction matters because technology research studies often confuse user acceptance with the capability of systems to operate at full capacity.

The findings indicate that successful innovation management for older adults requires organizations to create alignment among four essential areas: user-centered design, healthcare system integration, secure data governance, and holistic services. The combination of these dimensions forms a unified management framework that functions as a complete system rather than separate technological components.

## 6. Policy and Implementation Implications

For policymakers, the dominance of Technology Design Suitability and Healthcare Connectivity suggests that national digital health strategies should prioritize:

1. Age-friendly device standards
2. Interoperable health information systems
3. Clear data governance frameworks

In Thailand's super-aged societal context, smartwatch implementation should be treated not merely as consumer technology adoption but as structured healthcare infrastructure development. Public-private partnerships may be necessary to ensure standardized protocols for device integration within hospital and community health networks.

## 7. Clarification of Scope

The study evaluated healthcare stakeholder perceptions instead of studying older adult end-users. The results indicate system-level implementation priorities for the research but do not provide direct evidence about elderly user contentment, system usability, and user behavior adoption. Future research should examine how older adults perceive these dimensions and whether stakeholder priorities align with user experiences and outcomes.

## 8. Limitations and Future Research

Several limitations should be noted. First, the study was conducted in a single pilot province, which may limit generalizability. Second, participant recruitment at the professional level involved

convenience sampling, which may introduce selection bias. Third, the cross-sectional design limits causal inference.
Future research should:

- Conduct multi-province validation studies
- Compare stakeholder and elderly user perceptions
- Employ longitudinal designs to assess implementation sustainability
- Examine outcome variables such as quality of life, hospitalization rates, and caregiver burden

Structural modeling could also test causal pathways among components and their relationship to measurable health system outcomes.

## Institutional Review Board Statement:

This study involved only non-vulnerable adult participants and did not require the collection of sensitive personal data. Participation was voluntary, and informed consent was obtained from all participants prior to study commencement, either electronically or in writing. The study complies with the ethical standards of the Declaration of Helsinki (2013 revision). The research also complies with Thailand's National Research Council of Thailand [25], which stipulates that social and behavioral research carried out anonymously and involving no physical or psychological risk to participants is not subject to formal institutional ethics review in Thailand [29, 30]. Informed consent forms (ICFs) were obtained from all participants in the study.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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