

Research on Design of Elderly Diabetic Health Management Products Based on KJ-AHP Method

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ABSTRACT

To design health management products that better meet the actual needs of elderly diabetic patients and improve their quality of life. The KJ affinity diagram method was used to obtain the needs of the elderly for diabetes health management products, systematically organized and analyzed to form a list of 5 categories and 14 specific needs. With the aid of the AHP hierarchical analysis method, the weight of each indicator in the demand list was calculated. Through comprehensive weight ranking, five core functional indicators were identified: modular temperature control, integrated blood glucose injection pen, intelligent temperature control pen compartment, child supervision, and multi-level medication reminders. Based on the five core indicators, the design practice of insulin pens and insulin boxes that can be adapted and integrated was completed in accordance with the product design procedures and methods. Scientific analysis to clarify user needs and product functional characteristics can guide the design of practical, reasonable, and comprehensive health management products. The innovative design of insulin pens and insulin boxes focuses on core functions, responds to the pain points of elderly diabetic patients, provides a reference for the upgrade of similar products, promotes the development of health management products, and health security in aging societies.

Keywords: KJ affinity diagram method, AHP hierarchical analysis method, needs analysis, aging adaptation, product design.

INTRODUCTION

Diabetes, a chronic metabolic disorder characterized by hyperglycemia and insulin resistance, poses a significant global health threat due to its high prevalence, morbidity, and mortality, particularly among the elderly (Kalra & Sharma, 2018). The "Chinese Guidelines for the Diagnosis and Treatment of Diabetes in the Elderly (2024 Edition)" indicates that as of 2024, the number of diabetic patients aged 65 and over in China is approximately 35.5 million, accounting for a quarter of the global elderly diabetic population, and this number continues to rise (Li, Pan & Guo, 2024). The increasing aging of the population suggests a continued upward trend in the number of elderly diabetic patients. Insulin remains an effective treatment, with insulin pens being a common administration tool (Chentli, Azzoug & Mahgoun, 2015). Insulin is stored in the pen's cartridge, and the pen itself is a device that regulates dosage and facilitates injection (Wright, Bellone & McCoy, 2010). Common insulin pens include NovoPen, YpPen, and XilinPen. However, some elderly patients have limited knowledge of insulin pen usage and storage conditions, leading to misconceptions, such as consistently injecting into the abdomen for faster absorption or storing pens in the refrigerator. Furthermore, age-related physical decline can impair vision, making it difficult to read the pen's dosage scales, potentially leading to inaccurate dosing. Memory loss can also cause patients to forget injection times and dosages, even leading to repeated injections. The appearance of insulin pens, which resemble syringes used in hospitals, and the pain associated with injections can also cause fear and resistance (Kesavadev *et al.*, 2020). Short-distance travel necessitates carrying multiple medical devices and medications, such as blood glucose meters, test strips, lancets, insulin pens, needles, and alcohol swabs, which can be burdensome and difficult to manage. This paper will employ the KJ-AHP method, integrating user research and hierarchical analysis results to explore the functional requirements of the target product, clarifying the needs hierarchy of elderly diabetic patients. Based on the inherent logic, we will categorize and analyze these functions to provide safer, more convenient, and user-friendly health management solutions.

LITERATURE REVIEW

Product Function Optimization and Innovative Design

Pfützner, Pesach and Nagar (2017) demonstrated through laboratory data that insulin requires storage between 4-8°C, as extreme temperatures can cause degradation. The ViViCap-1, a thermal protection solution for disposable insulin pens, integrates chemical and engineering technologies, combining vacuum insulation and phase change materials. It maintains insulin temperatures $\leq 9^{\circ}\text{C}$ for over 12 hours at 37.8°C and can be "recharged" and reused below 26°C, ensuring safe and effective medication use in hot weather. Jain, Joshi & Mohanty (2019) noted the inconvenience and blood infection risks associated with traditional finger-prick blood glucose monitoring in diabetic patients, highlighting the need to address the limitations of invasive testing. To this end, research introduced the non-invasive "intelligent glucometer (iGLU)" device based on the Internet of Medical Things (IoMT), integrating near-infrared (NIR) spectroscopy with machine learning models. This approach uses non-

invasive optical signal acquisition and algorithmic analysis to accurately measure blood glucose, reducing the operational burden on elderly patients and improving their experience and satisfaction. Yang, Li and Qiao (2022) addressed issues of poor medication adherence and insufficient health monitoring in the elderly by designing a smart medicine cabinet system. This system integrates human-computer interaction and IoT technology, establishing a "device-home-medical" linkage model with simple dispensing and voice reminder functions, effectively addressing the problem of missed doses. Through APP communication with the medicine cabinet via WIFI, children can remotely set medication parameters, reducing medication risks, and adding temperature detection and trend monitoring to enhance health management capabilities.

Due to the combined effects of declining physiological functions and changing psychological characteristics, elderly diabetic patients have specific needs regarding operational convenience, safety protection, and emotional care when using products. Therefore, focusing on iterative optimization and innovative design of product functions has become a research area of significant practical and social value.

User Experience and Interaction Design

Yuan and Tang (2020) employed Kansei Engineering to segment user groups for home-use portable blood glucose meters. They collected and evaluated perceptual vocabulary from purchase feedback and actual usage scenarios to identify key factors influencing purchasing decisions. This approach facilitated product innovation beyond functional and technological limitations, emphasizing emotional and human-centered design to enhance user experience. Li and Li (2024) focused on elderly users of home blood glucose meters, thoroughly investigating their behavioral habits, emotional needs, and psychological characteristics. They integrated user requirements with design elements and user experience to develop a home health management product featuring user-friendly operation, intelligent result analysis, and multimodal information feedback, thereby significantly improving the psychological satisfaction and ease of use for elderly users. In an aging society, smart home products for the elderly often lack emotional design, leading to low user engagement. Curumsing *et al.* (2018) proposed an emotion-oriented requirements engineering method and developed the SofiHub platform, which integrates functional modules such as sensing, interaction, passive monitoring, and emergency assistance. Analysis indicated that this platform effectively alleviated loneliness in the elderly and enhanced their positive emotional experiences in smart home care scenarios.

The concept of optimizing product interaction experiences based on user behavior patterns and emotion-driven needs to enhance user satisfaction adheres to a user-centered design principle. It emphasizes in-depth insights into user behavioral habits, emotional needs, and psychological feedback, aiming to create natural, smooth, efficient, convenient, and enjoyable product interaction methods, thereby improving the user experience.

Sustainable Design Strategies

The escalating prevalence of diabetes globally has driven increased demand for medical devices, yet conventional models contribute to pollution and elevated carbon emissions. Patel *et al.* (2025) suggest that the circular economy, employing biodegradable materials and reverse logistics, can mitigate these environmental impacts, with digital technologies like AI and big data further aiding in carbon reduction. Their research systematically reviews the application of circular economy strategies in diabetic medical devices, demonstrating significant success in lowering carbon footprints and enhancing resource efficiency. Li (2022), focusing on the principles of age-friendliness and sustainable development, addresses the challenges faced by elderly individuals when traveling, particularly the inconvenience of carrying multiple medications and treatment devices for chronic diseases. She proposes a modular, sustainable design approach aimed at minimizing resource waste through reusable, flexible structural designs. Based on this, a geriatric diabetes care product was designed, integrating functions such as blood glucose monitoring, medication storage, and insulin injection through modular components. This design meets portability needs while reducing the environmental burden associated with medical device use, thereby promoting the development of age-friendly products towards green and sustainable practices.

In conclusion, sustainable design strategies provide new momentum for the development of age-friendly products. These strategies not only meet the diverse needs of elderly users in various scenarios but also maximize product value while effectively reducing resource consumption, improving user experience, and extending product lifespan. This approach minimizes waste, offering crucial practical directions and design concepts for promoting sustainable development.

NEEDS ANALYSIS FOR ELDERLY DIABETIC HEALTH MANAGEMENT BASED ON KJ-AHP

Preliminary Needs Analysis via KJ Method

The KJ method, also known as the Affinity Diagram, was developed by Jiro Kawakita. This method involves collecting textual data related to a product, categorizes it based on inherent relationships to clarify ideas, identify core issues, and generate innovative solutions. It is particularly effective in the needs exploration phase, efficiently integrating user requirements and assisting design teams in synthesizing complex information into clear functional needs.

The KJ method was employed to elicit the requirements of elderly diabetic patients for diabetes health management products. Specifically, the process comprised requirement collection, requirement experience and summarization, requirement grouping and categorization, and requirement list output. The specific implementation steps are detailed below (Scupin, 1997).

Requirements gathering phase

The core user group comprises 16 elderly diabetic patients, selected for this study based on the following criteria: urban residence, age 60-80 years, disease duration of at least 5 years, and either living alone or with family. An additional 10 indirect users were included: 5 family members or caregivers and 5 healthcare professionals providing insights into clinical needs and regulatory compliance. User pain points were extracted from the interview data and categorized as shown in Table 1.

Table 1: User Interview Pain Point Extraction

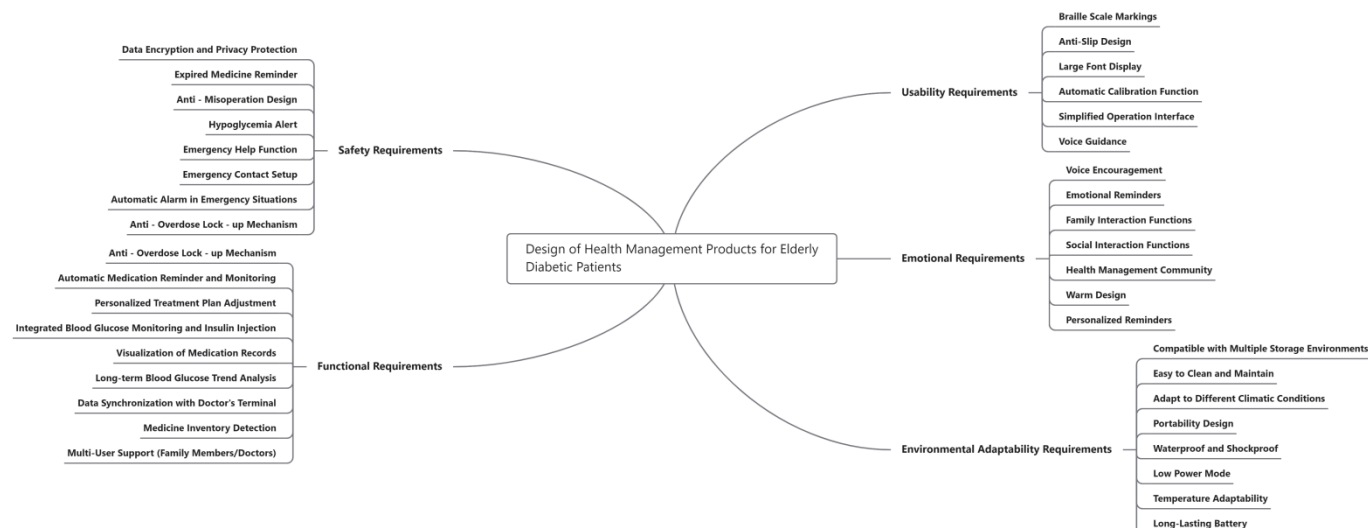
Serial Number	User Pain Points and Needs	Serial Number	User Pain Points and Needs
1	Patient U1: The cost of test strips and lancets is prohibitive; a reduction in consumable expenses is desired.	14	Patient U14: In emergencies, rapid family contact is desired.
2	Patient U2: Difficulty gripping the pen due to hand tremors; requests a non-slip grip on the pen body.	15	Patient U15: Device-generated recommendations based on test results are preferred.
3	Patient U3: Insulin rendered ineffective due to refrigerator malfunction during travel.	16	Patient U16: An overdose prevention mechanism is required to avoid incorrect dosage.
4	Patient U4: Severe presbyopia; tactile markings preferred for dosage accuracy.	17	Physician D1: Prevent hypoglycemia resulting from elderly user errors.
5	Patient U5: Requires voice prompts due to memory limitations regarding operational steps.	18	Physician D2: Rapid family notification is essential during hypoglycemic coma.
6	Patient U6: Interface complexity hinders ease of use and recall.	19	Physician D3: Trend graphs to facilitate adjustments to glycemic control plans are needed.
7	Patient U7: Visual impairment; difficulty reading numerical displays.	20	Physician D4: Limited hospital resources restrict comprehensive patient follow-up and guidance.
8	Patient U8: Frequently discovers medication depletion before reordering.	21	Physician D5: Real-time monitoring of patient medication adherence is challenging, relying on patient self-reporting.
9	Patient U9: Pain associated with finger-prick blood glucose monitoring.	22	Family F1: Pre-sorted medication in a drawer is safer for the elderly, who often mix medications.
10	Patient U10: Inconvenience of forgetting test strips while away from home.	23	Family F2: Remote access to the mother's medication schedule is desired.
11	Patient U11: High consumable costs for insulin pens and glucose meters; seeks more economical alternatives.	24	Family F3: Medication adherence monitoring, including a medication record, is needed.
12	Patient U12: Insulin storage challenges due to significant temperature fluctuations in winter and summer.	25	Family F4: Reminders should persist until acknowledged by the elderly user.
13	Patient U13: Inconvenience of managing multiple medical devices while traveling.	26	Family F5: Support and assistance are needed to alleviate the burden of care-giving.

Source: This study.

Centering on the pain points of such products identified through interviews, a brainstorming activity was carried out to obtain the functional requirement information of diabetes health management products, as depicted in Figure 1.

A systematic literature review reveals multifaceted needs among elderly diabetic patients within the context of health management. Regarding visual interaction, age-related cognitive decline, including diminished attention span, impaired information filtering, and reduced processing speed, hinders the rapid identification of critical elements and effective feedback in complex visual environments. Consequently, an efficient and precise alert mechanism is essential. In terms of health management, while the aging population often lacks systematic health management plans and targeted interventions, they express

a desire for independent chronic disease management and self-monitoring. Their primary need is to gain intrinsic motivation for continuous health management through accessible health information. In the realm of medication safety, the complexity of drug regimens combined with declining neurological function increases the risk of missed doses, duplicated medication, and improper usage among the elderly. Furthermore, a lack of fundamental medication knowledge among most elderly individuals exacerbates the potential for inappropriate medication use (Fialová & Onder, 2009). Regarding emotional support, elderly individuals living alone with limited mobility have a significant need for companionship. Meeting this need not only alleviates loneliness and anxiety and enhances life satisfaction but also optimizes the social support system in home-based care settings (Donovan & Blazer, 2020).



Source: This study.

Figure 1: Brainstorming Diagram of Functional Requirements

Requirements experience and overview

The user experience findings derived from the requirements gathering process indicate that, with advancing age, physiological responses manifest as the degradation of various organ functions, subsequently leading to multiple related complications (Wolff, Starfield & Anderson, 2002). Diminished memory, reduced learning capacity, presbyopia, and hearing loss represent the primary physiological challenges encountered by elderly individuals (Huang & Menozzi, 2014). Simultaneously, the rapid pace of societal evolution presents difficulties for some seniors in adapting their cognitive frameworks and lifestyles, thereby impacting product usability and user experience. For instance, current short-form video applications often inadequately address the needs of older users, exhibiting complex interfaces, information density, and operational difficulties, which restrict their engagement with digital life and social integration (Yan & Liu, 2022).

Research reveals that the majority of middle-aged and elderly users favor intuitive interaction methods, particularly those that enhance safety and convenience, such as automated alert systems, health monitoring functionalities, voice control, and simplified operations. These design elements facilitate their adaptation to new technologies, thereby increasing their receptivity to the proactive service features of smart products (Lu *et al.*, 2024). In terms of psychological needs, elderly individuals may experience feelings of loneliness and social isolation, a phenomenon particularly pronounced among those living alone or separately from their children. Their expectations for health management products extend beyond mere physiological health monitoring, encompassing a desire for emotional support and companionship, as well as personalized interactive experiences (Hu *et al.*, 2022).

Requirements grouping and categorization

Product feature requirements were consolidated through synonym merging and the elimination of redundant items, resulting in the formulation of feature cards for elderly diabetes health management products, as presented in Table 2.

Table 2: Functional Cards for Elderly Diabetes Health Management Products

Serial Number	Functional Requirements	Case Studies of User Needs	Serial Number	Functional Requirements	Case Studies of User Needs
1	Integrated blood glucose injection pen	Patient U13: There are too many medical devices being used now, making it inconvenient to go out.	8	Voice-guided injection	Patient U5: Exhibits difficulty in recalling procedural steps, necessitating auditory prompts.

Serial Number	Functional Requirements	Case Studies of User Needs	Serial Number	Functional Requirements	Case Studies of User Needs
2	Anti-slip textured pen body	Patient U2: Reports difficulty gripping the pen due to slippage; requests a pen body with anti-slip texture.	9	Anti-overdose locking mechanism	Physician D1: Prevents accidental hypoglycemia in elderly patients due to operational errors.
3	Smart temperature control pen chamber	Patient U3: Insulin became ineffective during travel due to refrigerator malfunction	10	Simple and intuitive interface	Patient U6: Interface is too complex, difficult to remember.
4	Multi-level medication reminders	Family member F4: Reminders should repeat until the elderly user confirms the action.	11	Child supervision function	Family member F2: Wishes to remotely monitor the mother's medication adherence.
5	One-touch emergency call	Doctor D2: Immediate family contact is crucial during hypoglycemic coma.	12	Medication records and confirmation	Family member F3: Seeking medication adherence records due to uncertainty about the elderly's medication compliance.
6	Health management data visualization	Patient U15: Requests device-generated recommendations based on test results.	13	Modular temperature control design	Family member F1: Advocates for compartmentalized drawers to enhance medication safety, addressing the issue of the elderly mixing medications.
7	Braille scale labeling	Patient U4: Enhanced tactile feedback is preferred due to severe presbyopia.	14	Medication inventory monitoring	Patient U8: Reports frequent instances of discovering medication depletion.

Source: This study.

Requirements list output

Using the KJ method, we subjected the initial 14 design requirements to hierarchical cluster analysis. Through semantic similarity assessment and functional domain mapping, first-level and second-level functional indicators were established. Furthermore, employing conceptual induction, the 14 second-level requirement indicators were consolidated into 5 first-level requirement indicators (Ding & Zhou, 2023), as presented in Table 3.

Table 3: Elderly Diabetes Health Management Product Requirements List

Serial Number	Level 1 functional indicators	Level 2 functional indicators	Serial Number	Level 1 functional indicators	Level 2 functional indicators	
1	Portability Requirements	Integrated Insulin Pen	8	Proactive Interaction Requirements	Multi-level medication reminders	
2		Intelligent Temperature-Controlled Pen Chamber	9		Child supervision function	
3		Anti-Slip Grip Design	10		Voice-guided injection	
4	Safety Requirements	One-Touch Emergency Call	11		Modular temperature control design	
5		Anti-Overdose Lock Mechanism	12		Health management data visualization	
6	Accessibility Requirements	Simple and Intuitive Interface	13		Health Monitoring Needs	Medication inventory monitoring
7		Braille Scale Markings	14		Medication adherence feedback	

Source: This study.

Prioritization of Requirements Weights Using the AHP Method

The Analytic Hierarchy Process (AHP), a well-established multi-objective decision analysis tool, was developed by Thomas Saaty in the early 1970s. This method constructs a hierarchical evaluation model, integrating expert pairwise comparisons of various indicators to form a judgment matrix. This process quantifies the relative importance of different requirement elements, ultimately determining a weight allocation scheme (Yue *et al.*, 2022). Its core value lies in transforming complex decision-making problems into a systematic quantitative analysis framework. The application of this method in medical product design has been widely validated, effectively addressing the quantitative decision-making challenges in prioritizing the functionalities of age-friendly products (Hou & Ran, 2024).

First of all, based on the list of needs of elderly diabetes health management products collated by the KJ method, the demand hierarchy analysis model is constructed, and the specific content is shown in Table 4.

Table 4: Hierarchical analysis model of demand for geriatric diabetes health management products

Design of Health Management Products for Elderly Diabetic Patients	
Criterion layer	Solution level
Carrying Convenience Requirement B ₁	Integrated Glucose Injection Pen C ₁
	Intelligent Temperature Control Pen Compartment C ₂
Safe Use Requirements B ₂	Non-slip textured pen body D ₁
	One-touch emergency call D ₂
	Anti-overload locking mechanism D ₃
Interaction accessibility requirement B ₃	Simple and intuitive interface E ₁
	Braille scale marking E ₂
Active Interaction Requirements B ₄	Multi-level medication reminders F ₁
	Child custody function F ₂
	Voice-guided injection F ₃
Health monitoring needs B ₅	Modular temperature control design G ₁
	Health management data visualization G ₂
	Drug stock monitoring G ₃
	Taking medication to determine feedback G ₄

Source: This study.

The objective is the design of health management products for elderly individuals with diabetes. Based on the KJ method, five criteria elements were extracted: B₁ (portability), B₂ (safety), B₃ (accessibility of interaction), B₄ (proactive interaction), and B₅ (health monitoring). Fourteen solution indicators were proposed accordingly.

Six design experts were invited to conduct pairwise comparison evaluations of the needs of health management products for elderly individuals with diabetes using a nine-point scale method. Based on the relative importance of each element in the indicator layer, a judgment matrix *A* was constructed, as shown in Equation (1).

$$A=(a_{ij})_{n \times n} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix} \tag{1}$$

In the judgment matrix, *a_{ij}* represents the relative importance of indicator *i* compared to indicator *j*. The comparison elements *a_{ij}* in the judgment matrix are measured using a 1-9 scale, with the reciprocal of the scale representing the inverse comparison. When *a_{ij}* is 1, it indicates that indicator *i* is equally important to indicator *j*; 3 indicates slight importance; 5 indicates significant importance; 7 indicates strong importance; and 9 indicates absolute importance. This process is used to determine the hierarchical functional indicator weight values for elderly diabetes health management products (Wang & Wong, 2024), with specific results presented in Tables 5 through 10.

Table 5: Judgment matrix and weights of target layer A

	B ₁	B ₂	B ₃	B ₄	B ₅	Weights ω ₀
B ₁	1	5	6	3	1	0.3616
B ₂	1/5	1	1/2	1/3	1/5	0.0568
B ₃	1/6	2	1	1/4	1/5	0.0707
B ₄	1/3	3	4	1	1/3	0.1614
B ₅	1	5	5	3	1	0.3495

Source: This study.

Table 6: Judgment matrix and weights for criterion layer B₁

	C ₁	C ₂	Weights ω ₁
C ₁	1	1	0.5000
C ₂	1	1	0.5000

Source: This study.

Table 7: Judgment matrix and weights for criterion layer B₂

	D ₁	D ₂	D ₃	Weights ω ₂
D ₁	1	1/4	1/3	0.1199
D ₂	4	1	3	0.6080
D ₃	3	1/3	1	0.2721

Source: This study.

Table 8: Judgment matrix and weights for criterion layer B₃

	E ₁	E ₂	Weights ω ₃
E ₁	1	1	0.5000
E ₂	1	1	0.5000

Source: This study.

Table 9: Judgment matrix and weights for criterion layer B₄

	F ₁	F ₂	F ₃	Weights ω ₄
F ₁	1	1	5	0.4545
F ₂	1	1	5	0.4545
F ₃	1/5	1/5	1	0.0909

Source: This study.

Table 10: Judgment matrix and weights for criterion layer B₅

	G ₁	G ₂	G ₃	G ₄	Weights ω ₅
G ₁	1	6	3	5	0.5869
G ₂	1/6	1	2	1	0.1566
G ₃	1/3	1/2	1	1	0.1307
G ₄	1/5	1	1	1	0.1258

Source: This study.

Finally, the consistency of the judgment matrix was tested according to Equation (2), where C_R represents the consistency ratio, λ_{max} represents the maximum eigenvalue of the judgment matrix, n represents the order of the judgment matrix (i.e., the number of indicators), and R_I represents the random consistency index. The consistency ratios (C_R) of the judgment matrices at all levels met the requirement of C_R ≤ 0.1, and all passed the test, indicating that the weight results were valid. The results are shown in Table 11.

$$C_R = \frac{\lambda_{max} - n}{(n-1) \times R_I} \tag{2}$$

Table 11: Results of consistency test of judgment matrix at each level

	matrix order	λ _{max}	CR	pass or fail
Guideline layer B	5	5.1753	0.0391	pass
Sub-criterion C	2	2.000	0	pass
Sub-criterion D	3	3.0741	0.0713	pass
Sub-criterion E	2	2.000	0	pass
Sub-criterion F	3	3.0000	0	pass
Sub-criterion G	4	4.1783	0.0668	pass

Source: This study.

The comprehensive weights for each alternative were calculated by multiplying the weights of each alternative for each criterion by the weights of the criterion layer and summing the results. These were then ranked, as presented in Table 12.

Table 12: Combined weighting ranking

Demand indicators	weighting	arrange in order
Modular temperature control design G ₁	0.2051	1

Integrated Glucose Injection Pen C ₁	0.1808	2
Intelligent Temperature Control Pen Compartment C ₂	0.1808	3
Child custody function F ₂	0.0734	4
Multi-level medication reminder F ₁	0.0734	5
Health management data visualization G ₂	0.0547	6
Medication stock monitoring G ₃	0.0457	7
Medication determination feedback G ₄	0.0440	8
Braille Scale Labeling E ₂	0.0353	9
Simple and intuitive interface E ₁	0.0353	10
One-touch emergency call D ₂	0.0345	11
Anti-overdose locking mechanism D ₃	0.0155	12
Voice-guided injection F ₃	0.0147	13
Non-slip textured pen body D ₁	0.0068	14

Source: This study.

FUNCTIONAL ANALYSIS OF GERIATRIC DIABETES HEALTH MANAGEMENT PRODUCTS BASED ON KJ-AHP

This study, grounded in an in-depth analysis of health management needs for elderly individuals with diabetes, employs the KJ-AHP method for systematic analysis and precise prioritization of these needs. The KJ method is utilized to organize user requirements through affinity diagrams, thereby extracting key functional points for product design. The AHP method further quantifies the weight of these requirements, clarifying functional priorities. Based on these findings, a modular health management system is designed for the elderly diabetic population, with insulin pens and insulin boxes as core components, aiming to enhance health management efficiency and quality of life. The functional design focuses on core requirements such as modular temperature control design (G₁), integrated blood glucose injection pen (C₁), and smart temperature-controlled pen compartment (C₂). Furthermore, functions such as child supervision (F₂) and multi-level medication reminders (F₁) are added to address active interaction needs, achieving comprehensive health management coverage.

Modular Temperature Control Function

The modular temperature control design is primarily implemented through the insulin box. An analysis of the technological evolution in the current insulin refrigerator market reveals that, despite the low penetration rate of modular temperature control systems (less than 30%), representative products from brands like Xinfei, Hainuo, and Haier offer valuable references in functional innovation. Taking the smart temperature control and storage system design as an example, its temperature control module can adopt semiconductor refrigeration technology (Yu & Zou, 2020). Through the collaboration of temperature sensors and controllers, the temperature is precisely controlled within the range of 2-25°C, meeting the storage requirements of long-acting, rapid-acting, and opened/unopened insulin types (Li, Zhao & Fan, 2025). Some advanced products can automatically adjust the refrigeration mode based on external temperatures, ensuring storage stability under extreme weather conditions. In terms of storage structure, these products generally adopt a modular partition design, setting up insulin pen slots, needle slots, and alcohol cotton layers to reduce the risk of contamination through physical isolation.

Based on the exploration of the advantages of existing insulin box designs in the market, the modular temperature control design of elderly diabetes health management products will adopt the strengths and make improvements. Six modular areas are designed, with different types of drugs and medical device partitions set up within each space, allowing for more organized storage and management of different types of drugs and medical devices, facilitating easy access and use, reducing the risk of cross-contamination, and ensuring the cleanliness and safety of drugs and devices.

Two of the modules are temperature-controlled areas, where the temperature can be adjusted and observed through a display screen, and one of the modules adopts a transparent design for easy observation of the internal situation, with a dedicated groove for storing insulin inside. The other four modules are normal temperature areas, which can store drugs and medical devices at room temperature. The switches of the module areas adopt a press-type rebound drawer design, allowing users to easily access drugs, enhancing usability and flexibility.

Integrated Blood Glucose Injection Pen and Smart Temperature-Controlled Pen Compartment

The integrated blood glucose injection pen and smart temperature-controlled pen compartment, addressing the need for portability, rank second in comprehensive weight. The pain points addressed by both requirements are related to the convenience of travel for elderly diabetic patients. Therefore, the difference between this insulin pen and ordinary insulin pens lies in its "multi-functional" feature—integrating blood glucose measurement, insulin injection, and smart temperature control functions.

This integrated design significantly improves the quality of life for elderly diabetic patients by reducing the number of devices they need to carry when traveling. The smart temperature control function can automatically adjust according to the ambient temperature, ensuring that the insulin is always in the best storage condition, effectively avoiding the problem of drug failure caused by temperature fluctuations.

Child Supervision Function and Multi-Level Medication Reminders

The child supervision function and multi-level medication reminders ranked third in the overall weighted value, representing two crucial interactive features in health management products for elderly diabetes patients. According to the seventh national census data, as of 2020, the number of empty-nest elderly couples' households in China reached 27.93 million, with 29.94 million households of elderly people living alone, totaling 43.56% of the total elderly households, which has become the main living arrangement for the elderly (Yang *et al.*, 2021). This situation leads to issues such as the absence of chronic disease management and delays in emergency treatment for elderly diabetes patients, especially in emergencies like falls or sudden illnesses, where immediate rescue mechanisms are lacking.

(1) Child Supervision Function: Through the insulin box, the health status of elderly diabetes patients is recorded. Remote monitoring and interactive technology enable children to understand their parents' real-time physical changes. Children can check their parents' health status at any time and any place through smart devices, promptly detecting abnormalities and taking corresponding measures. Conversely, elderly diabetes patients can also use the smart voice function to call the insulin box or use a one-button button for emergency calls (D_2) in emergencies. In addition, the child supervision function can provide customized health advice and reminders to help the elderly better manage their health.

(2) Multi-Level Medication Reminders: Ensuring that elderly diabetes patients take medication on time and in the correct dosage is crucial. This function provides timed reminders, medication confirmation (G_4), and drug inventory monitoring (G_3) through the visual screen of the insulin box, based on the patient's medication plan. It can also provide personalized reminder strategies based on the patient's medication adherence, such as increasing reminder frequency and providing medication education information. Furthermore, this function is combined with the child supervision function, allowing children to understand their parents' medication situation immediately, ensuring medication safety and effectiveness.

Simplified Design of Other Functions

In the comprehensive weighted value ranking, it was found that other functional solutions, such as E_2 , E_1 , D_3 , F_3 , and D_1 , performed at a lower level. Nevertheless, they still greatly enhance user experience and achieve product inclusivity, especially for specific user groups, such as visually impaired individuals or users with operational difficulties. Reasonable simplification design can significantly improve the product's usability and safety. The following are the key points of the simplified design for these functional solutions:

Visually impaired users face numerous challenges when using traditional insulin pens. Since most insulin pen designs primarily rely on visual feedback, visually impaired users find it difficult to accurately read the dosage scales, which may lead to dosage errors, thereby affecting treatment outcomes. By adding Braille markings (E_2) to the dosage adjustment area of the insulin pen, tactile feedback is provided for visually impaired users. This design allows users to perceive the dosage scales through touch, thus accurately setting the required insulin dosage. In addition to Braille markings, the voice guidance function (F_3) provides additional auxiliary support for visually impaired individuals or users who are not proficient in operation. Through the built-in voice module, the insulin pen provides real-time voice prompts during the user's operation, including dosage setting, injection preparation, and operation completion.

Safety use requirements are more of an auxiliary function. For example, the overdose locking mechanism (D_3) and the non-slip texture pen body (D_1) are both designed to reduce user operational errors, improving product safety and user trust in the product.

PRACTICE OF PRODUCT DESIGN FOR SENIOR DIABETES HEALTH MANAGEMENT BASED ON KJ-AHP METHOD

Based on the systematic analysis, weight ranking, and functional analysis of the demand for geriatric diabetes health management class products by KJ-AHP method, in order to satisfy the core needs of geriatric diabetes users and to improve the ease of use, safety and portability of the products, the insulin pen and insulin cartridge were designed with functional integration, structure and appearance respectively.

Design of Insulin Pen

The design of the insulin pen focuses on the multidimensional needs of portability, safety and interactivity. It integrates noninvasive glucose monitoring and noninvasive insulin injection into an integrated process, in which the noninvasive technology realizes glucose detection and insulin injection in a noninvasive way without needling the skin, which is especially

suitable for continuous glucose monitoring, and can effectively alleviate the psychological burden of needing for elderly users (Gonzales, Mobashsher & Abbosh, 2019). At the same time, its integrated design greatly streamlines the operation process and reduces the number of devices to be carried, which is convenient for elderly users to use outside. The intelligent temperature control function continuously maintains the appropriate temperature range to ensure insulin stability and injection accuracy. The device features a small LCD screen for human-computer interaction. By optimizing the interface layout and adopting the function of adjustable font size, it effectively enhances the readability of information and accurately adapts to the needs of elderly users with declining eyesight. In addition, the device has a built-in IoT module (Yashiro *et al.*, 2013), forming a modular design with the insulin cartridge, which can realize the functions of large screen display and intelligent analysis. When out and about, if the test results show abnormalities, the insulin pen will pass the information to the insulin cartridge in real time. Both devices adopt visual, auditory, and tactile multimodal interaction to provide comprehensive and timely notifications to elderly users and their caregivers in different scenarios, ensuring the accuracy and convenience of the information conveyed, and providing them with a more humanized and barrier-free medical testing solution, with the design effect shown in Figure 2.



Source: This study.

Figure 2: Effectiveness of insulin pen design for geriatric diabetes health management

Design of Insulin Box

The design of insulin cartridge echoes the core elements extracted from the functional analysis, and takes safety, interactivity and health monitoring as the main points of design, and builds a product system that meets the needs of elderly diabetic patients with insulin pen. As a modular component, it not only seamlessly connects with the insulin pen in terms of function, but also improves the convenience and ease of use of the whole system by optimizing the structural design and upgrading the user experience. The device mainly includes modular temperature control design G_1 , multi-level medication reminder F_1 , health management data visualization G_2 , medication stock monitoring G_3 , and medication determination feedback G_4 , and other system functional designs. The core control unit is an embedded microcontroller ARM (Nyapathi *et al.*, 2016), and the detection unit consists of a load cell, a temperature sensor and a photosensitive sensor, where the load cell is used to monitor the medication taking and the temperature sensor is used to detect the environment temperature. The alarm unit consists of a buzzer module, a voice sensor and a GSM SMS module to realize the multi-modal alarm function. Relying on modern electronic technology, the smart insulin cartridge revolutionizes the traditional drug-taking mode, utilizing sound and light reminder and voice broadcasting functions, which can not only timely urge elderly diabetic patients to take injections and medications on time, but also push drug information to the guardian's cell phone in real time, which significantly reduces the risk of omission and incorrect dosage, and effectively improves the quality of life of the elderly.

In terms of structural design, the top of the box body is designed with a circular array of cooling holes to enhance the cooling efficiency and durability of the device. At the top of the box, a slot is designed for storing the matching insulin pen, which integrates the pen and the box into a unified management system, deepening the modularization and integration design. In addition, the small hand-controlled light at the top of the box is designed for nighttime or low-light environments, which can be lit by elderly users with a light touch to provide illumination for medication pickup, taking into account both convenience and safety, and fully adapting to the needs of the visually impaired group, with the design effect as shown in Fig. 3.



Source: This study.

Figure 3: Effective design of insulin cartridges for geriatric diabetes health management

CONCLUSION

In this paper, the needs of elderly diabetic patients for health management products are analyzed in depth through the KJ-AHP method, and the KJ method sorted out five categories of first-level needs and 14 specific functional indexes for ease of carrying, safe use, easy accessibility, active interaction, and health monitoring; the Hierarchical Analysis Method clarifies the modular temperature-control design, the integrated glucose injection pen, the intelligent temperature-control pen compartment, the children's monitoring function, and the multilevel medication reminder as the core needs with higher weighting values through the quantitative analysis. Hierarchical analysis clarifies the modular temperature control design, integrated blood glucose injection pen, intelligent temperature-controlled pen compartment, child monitoring function and multi-level medication reminder as the core requirements with higher weighting values. Based on the results of this analysis, a set of insulin pens with modular health management system, integrated non-invasive monitoring, injection and temperature control functions is designed, which not only solves the problem of inconvenient carrying of multiple devices, but also eliminates the fear of injection in the elderly, and significantly improves the convenience and safety of use by matching with age-adapted interaction methods. The design of insulin cartridge with partitioned temperature control, intelligent monitoring and emergency function can realize the orderly storage of insulin and other medicines, which can guarantee the safety of medication in an all-round way. The analysis and design practice in this paper can provide reference for the innovative design of geriatric diabetes health management products and help improve the quality of people's life in the aging society.

ACKNOWLEDGMENT

This work was sponsored by the Major project of Philosophy and Social Science research in colleges and universities of Jiangsu Province (2023SJZD108), Ministry of Education Human Society project of China (22YJC760024), and sponsored by 2023 Qing Lan Project.

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