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Design of Smart Underwear Nursing Service System to Assist Elderly Walking based on Kano Model

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Abstract
This study was to design an intelligent underwear nursing service system that can assist the elderly in walking according to their original demand for intelligent underwear fall prevention. The research proposed an intelligent underwear nursing service system that integrates the App through the Kano model, which was analyzed with the help of the Four-Quadrant Scatter Model Plot model diagram. Monitoring Service Interaction Subsystem, Monitoring Sports, and Health Management of the intelligent nursing service system. This result indicated that the demand satisfaction rating that the smart underwear nursing service system assists elderly walking was scientific, effective, and fulfilled the needs of elderly users.

Keywords: Kano model; service system; smart underwear; oderly

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1.0 Introduction

The World Health Organization shows that the aging population will rise to nearly 25% of the global population in 2050; this number can even reach developing countries(World Health Organization,2020). According to the National Bureau of Statistics data, as of 2019, the population aged 65 and above in China accounted for 12.6%, with a population of 176.03 million, an increase of 9.45 million or 0.7 percentage points over 2018. From the international comparison of the aging level, the proportion of the global population aged 65 and above will be 9.1% in 2019, and the aging ratio of China's population has far exceeded the global value. However, with the continuous improvement of living standards, the elderly's demand for outdoor health sports is also rising. The safety of outdoor sports for the elderly is increasingly important because many physiological diseases occur at this age, such as heart disease, hypertension, limb function degradation, etc. Therefore, developing smart elderly healthcare techniques is of vital importance.

1.1 Problem Statement

The smart underwear for older people used in this study was designed and developed by X.J. Yan. They are already implemented in sports care or nursing homes and may be commercially available(Lee & Zhou, 2017; Murphy, 2017; Preston & Stokes, 2012). However, the application of smart underwear in outdoor and home settings, as well as home caregivers providing care for elderly people with high blood pressure, has not been studied. Another visit was conducted by a research nurse, who was accompanied by an engineer to install the flexible smart sensing elements. During the first month after the sensors were installed, researchers and nurses visited the

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participants' homes and outdoors every ten days for indoor and outdoor interventions and to address issues using the smart underwear-assisted walking care delivery system. Qualitative data:

To provide comfort, safety, and function features on clothing for older persons through a smart underwear nursing system. The researchers conducted group interviews and group discussions. According to the interview guidelines, each interview lasted ten older people per day, 60 minutes, and lasted for three days. Sample questions include: Can you describe a difficulty in your life? What kind of care do you provide? What has your experience been using the smart underwear-assisted walk-nursing service system? Moreover, they visit 5-10 nursing homes to observe their behavior and to see the actual problems they are facing when they walk. Sample questions include: In what ways has the smart underwear-assisted walk-nursing service system been helpful or not helpful in your caregiving? what has been walking difficult for the care recipient(60 years of age and above) or caregivers about using the smart underwear-assisted walk-nursing service system

1.2 Research Objective

1): To use the 10-item Chinese Barthel Index (CBI)20to measure older person's activities of daily living (ADLs), including eating, transferring, grooming, toileting, bathing, walking, climbing stairs, dressing, as well as bowel and bladder control, and then especially walking and transferring. Total CBI scores range from 0 to 100. The higher the score, the stronger the independence and the lower the dependence;

2): To build the small sample size (n = 10), a non-parametric Friedman test of difference was used to compare repeated measures and post-analysis to determine whether there was a significant change in the effectiveness scores of smart underwear in helping the elderly walk. Analyze data using SPSS 17.0.

1.3 Research Significance

This research is collected only for caregivers of older adults with hypertension, as it is not the case for older adults recovering from slips and falls. Therefore, quantitative assessments of elderly caregivers with hypertension and slips are unlikely to be influenced by the home-care researcher transcribed interviews. Description and interpretation are important for qualitative data acquisition, including keywords and sentences expressed by researchers and interviewees. The description implies little interpretation to reduce the data to keywords and phrases, whereas interpretation involves the interpretation of the research based on the purpose of the research. Respondents included older adults and their family caregivers. By asking questions and communicating, from their descriptions of the difficulties and inconveniences in the daily care of the elderly, as well as detailed explanations of the need for smart clothing to assist elderly care, determine the real needs of elderly users and family care members for smart clothing. Description and interpretation are important for qualitative data acquisition, including keywords and sentences expressed by researchers and interviewees.

2.0 Literature Review

The fast-growing of wearable devices has brought their application in smart care, including smart clothing （Medina et al.,2022; Tuna et al., 2021). Smart wear5.0 Wireless technology wins for non-invasive sensors that have been integrated into clothing to enhance biomedical data collection to monitor wearable physiological parameters, prevent disease, and enhance safety(Rouzbahani et al.,2022; Ismail et al., 2021; Nguyen et al., 2021). Great research has been done in the field of smart health care for older persons.S Imbesi et al.9 describe a user-centered methodology for the design of smart garments based on the evaluation of users' acceptance of smart clothing and to evaluate the general response of each garment typology to different categories of requirements, determining the propensity of the older user to the utilization of the developed product. J Beltrán et al. (Beltrán et al.,2016) envision a futuristic scenario with smart clothing for disabled and older adults using spray fabric combined with nanosensors.

The effect of clothing pattern and fit in EMG applications using e-textile electrodes integrated onto the sleeves of custom-drafted t-shirts in set-in and raglan sleeve pattern variations for older persons(Tuna, 2021). Developed smart tiles-based elder tracking and fall detection system, which used pressure sensors and accelerometers hidden under the smart tile(Daher et al.,2016). Presented an overview of the smart electro-clothing systems (SeCSs) targeted at health monitoring, sports benefits, fitness tracking, and social activities, and it also presented the developments in the associated areas of wearable sensor systems and textile-based dry sensors, which encoded the pressure information(Sayem et al., 2020).

3.0 Methodology

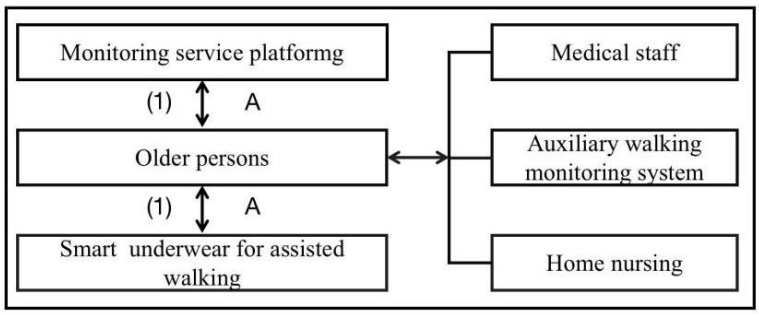
3.1 System design

The research of the proposed smart underwear-assisted walk-nursing service system for older persons is illustrated in Figure 1. The system was mainly composed of three parts :(1)Smart underwear, high blood pressure monitoring sensing components, and electronic muscle stimulation components are responsible for receiving data;(2) exercise-nursing care control platform, responsible for health data analysis and abnormality alert; and (3)device, responsible for displaying of data and warning of abnormal events, and for providing service. The smart underwear assisted collected HBP signals and anti-fall monitoring through seven flexible electrode patches. Then it transferred the analog HBP signals and anti-fall signals to the sensing component through flexible, intelligent components. The sensing component converted the HBP, analog, and anti-fall signals into digital signals. The sensing component's microprocessor unit(MU) and smart chip unit (SCU) analyzed digital HBP signals and anti-fall monitoring in real time using specific algorithms. The HBP and anti-fall

posture data were then transmitted through fifth-generation(5G), which were received by the 5G- wifi in the environment. The 5G- wifi receiver transmitted the received data to the back-end management platform for analysis, where the data were finally converted into meaningful health data. The health data were presented in Web and APP mode to the mobile terminal device of the caregiver and nurse station.

3.2 Service system

The intelligent underwear nursing service system that the nursing service module uses to assist the elderly in walking comprises three parts: an intelligent assisted walking system, an online monitoring system, and a monitoring service interaction system. Wifi and 5G networks link the three modules to speed up the sensitivity and effectiveness of data transmission and walking-assisted nursing. The intelligent assisted walking system provides real-time care for the elderly's human joints and muscles through intelligent electronic muscle components. It sends the health walking safety index and human health data to the monitoring system. After receiving the data feedback, the monitoring system sends nursing instructions to the nurses or doctors through the nursing service terminal APP system on time. It evaluates the effect of intelligent assisted walking through the offline monitoring service system. The specific nursing service system framework is shown in Figure 1.



Note: A refers to the intelligent auxiliary walking system, (1) refers to an online monitoring system, (2)refers to a monitoring service interaction system

Fig. 1: Framework of Intelligent Nursing Service System

(Source: Author)

3.2 Identification of Needs

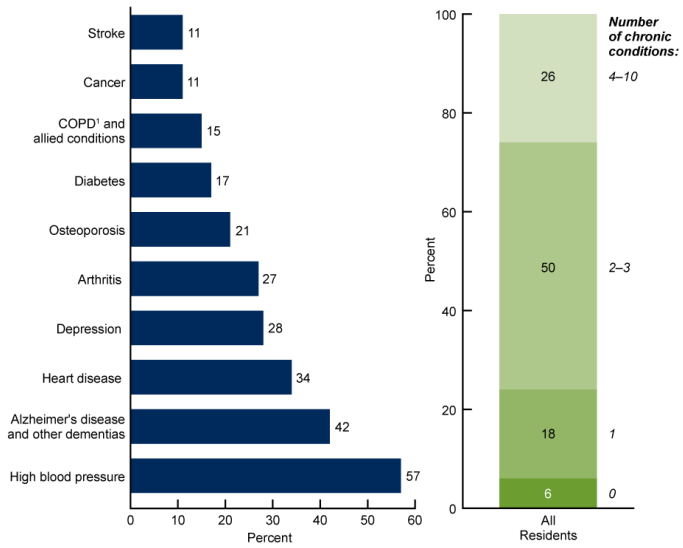


Fig.3: Diseases with the highest prevalence among the elderly

（Source: Cameron et al., 2022)

Since the 21st century, China has gradually entered a stage of moderate aging. A characteristic of this aging process is the population aged 60 and above, where, due to aging, various bodily functions start to decline, leading to prominent health issues. Many scholars believe that over two-thirds of the elderly population is currently afflicted by chronic diseases. As shown in Figure 3-6, chronic diseases such as hypertension, diabetes, and cardiovascular diseases have become vital factors affecting the health of the elderly. This sizable group of individuals with health problems experiences a deteriorating health condition, with some even becoming disabled or semi-disabled, significantly inconveniencing their lives.

Furthermore, another characteristic of the current aging trend is the diversity in the health of elderly individuals, as depicted in Figure 2, illustrating functional changes in the human body during life. It can be observed that the functional scope of the elderly is more extensive than that of younger individuals. While the cognitive functions of individuals aged 60-89 are similar to those of a 40-year-old, some individuals aged 60 and above require assistance from others or assistive devices to complete or improve their basic physiological or social activities.

The above research shows that individuals aged 60-89 are increasingly concerned with adopting scientifically reasonable indoor and outdoor activities and maintaining a healthy lifestyle. Therefore, enhancing health monitoring and care services for the elderly becomes a significant factor in improving the current aging situation, posing a new challenge for researchers in the direction of smart clothing and its service systems.

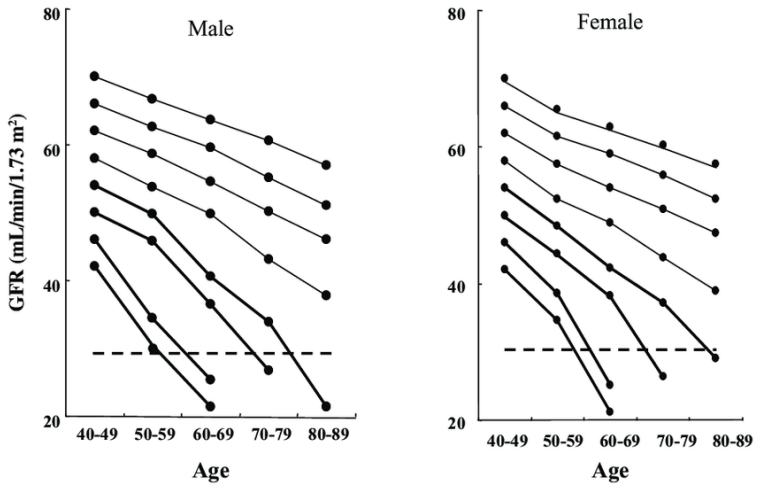


Fig.4: Functional changes during human movement
（source: Kritmetapak et al., 2020)

4.0 Findings

4.1 Kano model

Kano is a tool Noriaki Kano of the Tokyo University of Technology proposed on the classification and prioritization of user needs, which is used to analyze user needs and satisfaction and reflect the nonlinear relationship between product functions and user satisfaction(Hui et al., 2021). Based on the user's psychological experience and needs, the user's demand satisfaction is analyzed. Obtain the jurisdiction between user requirements and product functions and quality to sort the user requirements, which plays a great guiding role in the innovative design of products.

4.2 Participants

A convenience sample of caregivers of older persons and older people with high blood pressure and mobility difficulty was recruited from a nursing center home in Zhejiang Province, China. The researcher identified caregivers of older persons who met the research criteria as potential participants and explained the study's design and purpose. Interested caregivers and elders were invited to participate, and those who agreed provided signed informed consent.

These criteria include older adults who: (1) are over 60 years old; (2) have been diagnosed with hypertension and have mobility difficulties; (3) can walk independently or with assistance; (4) do not have a first family caregiver; (4) Live in a nursing home. The nursing staff was included in the following criteria: (1) ≥30 years old, (2) responsible for providing indirect care. (3) able to walk independently or with assistance; (4) receiving care from family caregivers for kinship and community hospitals for personal ties.5.0 Discussion

5.0 Discussion

5.1 Experiments1:Smart assistant analysis of underwear demand factors for older persons

Through non-immersive interviews and field research on the elderly, and finally, through a questionnaire survey, we sorted out the contact points in the service demand, analyzed the experience and feeling of intelligent underwear to assist the elderly to walk, and obtained 12 original needs of elderly users for the experience of assisted walking products, as shown in Table 1. At the same time, similar original requirements are summarized and integrated to form four user experience demand elements, as shown in Table 2.

Table 1. Description of the original demand for intelligent underwear to assist the elderly to walk

1. Health Coaching	5. Auxiliary walking record	9. Emergency call for rescue
2. Fall warning	6. Auxiliary exercise record query	10. Joint-assisted massage
3. Security Tips and Alerts	7. Remind to walk on time	11. Communication between nurses and doctors
4. Auxiliary walking function prompt	8. Telemedicine	12. Assisted walking consultation

(Source: Author)

Table 2.Demand Integration of Intelligent Underwear for Assisting the Elderly to Walk

Number	Original demand information of elderly users	Demand integration
①	1.Health coaching ; 4.Auxiliary walking function prompt ; 7.Remind to walk on time	Auxiliary walking file
②	2. Fall warning ; 3.Security Tips and Alerts ; 9.Emergency call for rescue	Timely communication with the nursing staff or doctors
③	5. Auxiliary walking record ; 6.Auxiliary exercise record query	Convenient auxiliary walking
④	8.Telemedicine ; 10.Joint assisted massage ; 12.Assisted walking consultation ; 11.Communication between nurses and doctors	Depth-assisted walking function

(Source: Author)

Kano analysis of demand elements designed questionnaires for the integrated four user needs experience. Through online and paper questionnaires, 105 valid questionnaires were collected, summarized according to the classification table, and statistically analyzed the views of elderly users' needs, as shown in Table 3. A questionnaire for the user needs of "deep assisted walking" was obtained. A total of 98 people believed that the needs were basic needs (M).

According to the classification in Table 2 above, analyze and sort out the demand results of the remaining three items of user needs and substitute them into formulas (1) and (2) to calculate satisfaction Si and dissatisfaction Di, as shown in Table 4.

Table 3. Investigation and Statistics of Basic Needs of Intelligent Underwear for Assisting the Elderly to Walk (Deep Assisted Walking Function)

Basic needs	Negative problems (dissatisfaction with basic needs)				
Depth-assisted walking function	Satisfied	For this reason	Indifferent	Dislike	Extremely dissatisfied
Forward question	30	69	5	1	0
Meet the depth-assisted walking function	25	60	10	5	5

(Source: Author)

Table 4.Statistics of Demand Attribute Results of Satisfaction Si and Dissatisfaction Di

Project	Satisfaction （Si）	Dissatisfaction （Di）
①Establish personal assisted walking files	0.85	0.37
②Timely communication with the nursing staff or doctors	0.52	0.28
③Convenient auxiliary walking	0.83	0.42
④Depth assisted walking function	0.69	0.41

(Source: Author)

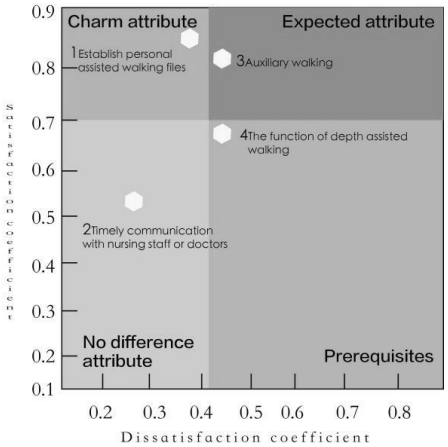


Fig.5: Kano Four quadrant Scatter Model

(Source: Author)

With the help of the Kano four-quadrant scatter model diagram, a scatter diagram of the user demand for the intelligent underwear nursing service system assisting the elderly to walk was constructed, as shown in Figure 5. The "deep assisted walking function" is an essential attribute of the elderly users, which is the first demand, and should be optimized and improved as much as possible; "Assisted walking convenience" is the expected demand of elderly users, the key to superior product competitiveness, and also a design point different from other products; "Timely communication with nurses or doctors" is an exciting demand of elderly users. Once this demand is well met, user satisfaction and dependence will be rapidly improved. "Creating Personal Assisted Walking File" is a user's undifferentiated attribute, which can be ignored under certain conditions.

5.2 Experiments2:Design of smart underwear nursing service system

Based on the three modules of the intelligent assisted walking system, online monitoring system, and offline monitoring service system, through the interaction between elderly users - intelligent muscle elements for assisted walking - mobile terminal APP, and according to the inherent nursing behavior, interaction behavior and monitoring behavior for assisted walking, the interactive identification and function building of intelligent muscle elements and terminal service system APP is ensured. The APP interaction interface is shown in Figure 6. The theme vision of APP interface content is mainly orange, red, and blue, which can alleviate the visual fatigue of the elderly and improve their terminal recognition ability.

Fig.6: The terminal interface of the assisted walking nursing service system
(Source: Author)

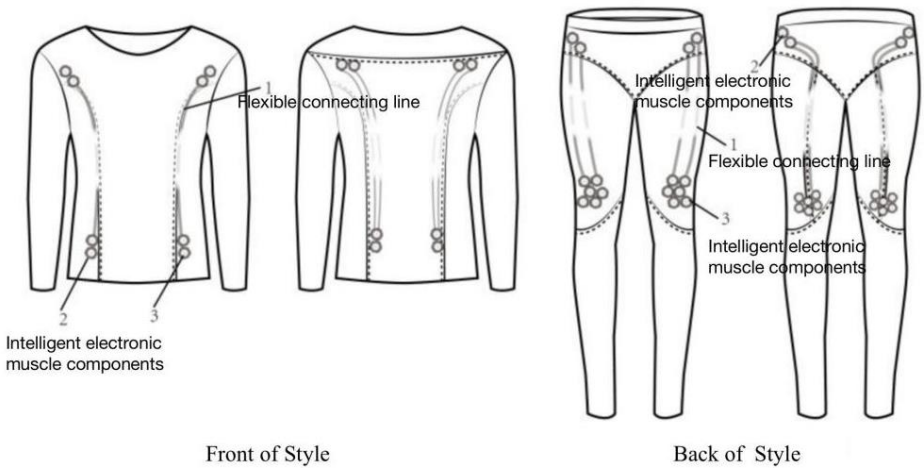


Fig.7: Style of the elderly's smart underwear in autumn and winter
(Source: Author)

Considering the needs of the elderly for warmth preservation in autumn and winter, this study takes the elderly's thermal underwear as the research object. The main style features are as follows: round neck and narrow sleeves, tight cuffs and cuffs, tight body fitting, knife back seam design of the jacket, and cut line design of the back, side waist, and middle thigh, as shown in Figure 7. In the style design, through the embedded process, the flexible connecting line 1 of the intelligent electronic muscle element is hidden in the

underwear style to connect the intelligent electronic muscle elements 2 and 3 effectively. As an important flexible intelligent component 3 to assist the elderly to walk, a single intelligent component can be designed according to the size of the contact area with the human body, or the shape of multiple intelligent components can be combined to form a circle, triangle, diamond, etc.. The smart chip controller, Bluetooth protocol stack, flexible electrode patch, pulse transmitter Lithium battery and other devices transmit signals and enhance the intensity and frequency of muscle massage for the older persons(Jia et al., 2020; Tuna et al., 2021; Medina et al., 2022).

6.0 Conclusion & Recommendations

According to the emotional needs of the elderly users for habitual assisted walking, 105 valid questionnaires were analyzed. The reliability evaluation method was used to evaluate the reliability of eight indicators, including the style characteristics I, the intelligent components U, the assisted walking system D, the monitoring system E, the monitoring service system F, the fabric M, the comfort B, and the safety and functionality S of the intelligent underwear used to assist the elderly to walk. See Table 1 for details.

Table 5. Reliability Evaluation of Intelligent Underwear Products Assisting the Elderly to Walk

Rating indicators	Corrected item-total correlation(CICT)	Cronbach coefficient (α)
Style characteristics of intelligent underwear(I)	0.42	0.81
Intelligent components for auxiliary walking (U)	0.64	0.72
Auxiliary walking system (D)	0.54	0.82
Monitoring system (E)	0.67	0.72
Monitoring service interaction system (F)	0.71	0.92
Fabric (M)	0.38	0.53
Comfort(B)	0.52	0.62

(Source: Author)

Corrected item-total correlation (CICT) and Cronbach coefficient as shown in Table 4 （ α） .SPSS17.0 was used for reliability evaluation analysis, and Cronbach coefficient(α)When ≥ 0.7, the user has a high degree of feasibility for the evaluation index. When the Kronbaha coefficient(α) ≤ 0.3, the user's feasibility of the evaluation index is low and can be ignored. According to the data analysis in Table 1, the Kronklonbach coefficient of monitoring service interaction system F(α) is 0.92, and the evaluation reliability is the highest among all indicators, followed by the assisted walking system D and the style feature I of intelligent underwear. The rest α Values are greater than 0.3. This shows that the intelligent underwear assisting the elderly to walk has good market demand and application value in terms of style modeling, fabric properties, comfort, and safety, as well as a good service system of intelligent components for walking assistance, and the design should be emphasized.

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Paper Contribution to Related Field of Study

This research also contributes to smart clothing design-related studies that measure what would best fit to Assist Elderly Walking.

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