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BRACKET: A Smart Pad Adjusts Automatically to Optimize the Design for Preventing Decubitus Ulcers in Older Persons Who Have Been Lying Down for a Long Time

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Abstract. The goal of this thesis is to investigate the design application of the smart pad automatic adjustment mechanism in addressing the improvement of prolonged lying posture, pressure ulcer prevention, body detection, and rehabilitation healing of the elderly. Prolonged lying down is hazardous to the elderly's health and can easily lead to pressure ulcers and other complications. BRACKET has a built-in pressure sensor and an automatic adjustment mechanism that can monitor real-time changes in the elderly's sitting posture and body posture and automatically adjust the cushion morphology and hardness to optimize the pressure distribution based on the data fed back from the sensor to effectively improve the prolonged lying down posture and prevent the occurrence of pressure ulcers. The study describes in detail the design principle and automatic adjustment technology of BRACKET, and the impacts of BRACKET in different sedentary postures are evaluated and compared with typical seat cushions via experiments and data analysis. BRACKET greatly reduces local pressure and effectively reduces the harm of pressure ulcers, as well as providing better sedentary care and rehabilitation services for the elderly, reducing the burden of care, and making a positive contribution to the improvement of the quality of life of the elderly and the effect of rehabilitation.

Keywords. Intelligent pad design, automated adjustment, elderly people lying down for long periods of time, pressure ulcer prevention

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1. Introduction

Decubitus ulcers, also known as pressure ulcers, are most common among the elderly who are bedridden or sedentary for extended periods of time. Prolonged recumbency in the elderly is not only prevalent, but it is also one of the primary causes of significant consequences such as pressure ulcers. Decubitus ulcers are related with extended exposure of local tissues to persistent pressure, ischemia, and hypoxia, resulting in skin and tissue damage and even ulcer formation[1].Decubitus ulcers not only cause physical pain and discomfort, but they can also develop to complications such as infections and osteomyelitis, which have a negative impact on patients' quality of life and increase the usage of healthcare resources. The prevention and treatment of decubitus ulcers in the elderly is a critical healthcare issue. However, there has been minimal research into the development of smart pads for the prevention of decubitus ulcers in the elderly. Traditional techniques of preventing decubitus ulcers are mostly based on the principle of air alternation, but they have disadvantages such as inability to turn over automatically, high cost, and noise interference. As a result, the purpose of this thesis is to investigate the design and use of smart pad's automated adjustment mechanism in optimizing the prevention of decubitus ulcers in the elderly in a lengthy and extended lying situation. BRACKET, a novel nursing aid with built-in pressure sensors and an automatic adjustment mechanism, continuously checks the elderly's prolonged lying posture and leg muscle condition. BRACKET automatically modifies the form and hardness based on sensor data to relieve leg pressure, enhance blood circulation, avoid bedsores, provide relevant suggestions for geriatric care design and rehabilitation, and improve quality of life. This paper will describe the BRACKET design, sensor configuration, automatic adjustment mechanism principle, and user interaction system, as well as present the experimental design and results to quantitatively and qualitatively evaluate BRACKET performance and automatic adjustment effect. The user experience will also be prioritized in order to collect and analyze feedback from older persons in order to better understand their perceptions of the automatic adjustment function and bedsore prevention effect.

2. Related work

After gathering pertinent material and doing fieldwork on the subject, the study team broadly classified the work as existing research on sedentary care for the elderly, as well as research advancements in the fields of automatic adjustment technology and human-computer interaction systems.

2.1. Progression in the prevention of senior decubitus ulcers

The health risks associated with extended laying, as well as the severity of bedsores in the elderly, have sparked great interest, and the medical and research communities have advocated a range of approaches for preventing bedsores. As a result, research seeks more innovative and clever solutions.A continuous monitoring system, for example, analyzes body temperature, skin wetness, and prolonged lying, releases air at the appropriate temperature through mattress vents, and allows remote monitoring via a mobile app [2]. Bedsore preventative care garment development and design have also been offered, along with some viable suggestions[3]. old care systems, such as

notification systems, bed prediction systems, and real-time monitoring systems, have been created to monitor the behavior of old patients in bed [4].Wearable soft microfluidic pressure sensors based on 3D printed microbumps and liquid metals, as well as their potential applications in health monitoring via biosignals and body pressure data collected by the proposed pressure sensors, which can be used to aid in the early diagnosis and prevention of diseases such as diabetes and bedsores [5]. Traditional mattresses use materials such as foam and cotton, and air mattresses are filled with gas, but they have limitations such as insufficient morphological adaptability and difficulty in accurately adjusting firmness and pressure distribution, which limit their effectiveness in preventing bedsores. Research on prolonged decubitus ulcer prevention in the elderly has introduced innovations in continuous monitoring systems and nursing apparel, but has also faced potential challenges and limitations in terms of user psychological self-esteem, user adaptability, and practical applicability of the products. Therefore, research tends to seek more innovative and intelligent solutions.

2.2. Automatic Adjustment Technology and Human-Computer Interaction Technology Research Progress

Rapid breakthroughs in artificial intelligence and human-computer interaction are introducing novel approaches to the challenge of preventing pressure ulcers in inactive older individuals. Many studies in the field of pressure-sensing technologies have used sensors and data collecting techniques to monitor the sleeping postures and pressure distribution of older persons in order to forecast the risk of ulcers. A low-cost solution with high accuracy and reliability and the ability to detect compensatory motion mattresses[6]. Caregivers can additionally monitor the patient's posture and mattress status in real time, as well as remotely change the mattress shape, using a mobile app-based remote monitoring system[7].Similarly, cloud-based technologies enable caregivers to monitor and change beds in real time from anywhere in order to provide patients with individualized sedentary care[8]. Furthermore, studies have revealed that different mattresses have distinct impacts on comfort and ulcer prevention, with polyolefin mattresses giving more support, lowering pressure, and relieving pressure concentrations in important places[9]. A prototype for caring for patients with ulcers that controls standardized sniffing pressure levels by receiving feedback from the patient and the pressure state of the bed is also available[10]. Although these novel techniques give hope for the prevention of pressure ulcers in inactive elderly persons, research still faces several hurdles.

3. Design and implementation of intelligent pads

Through an automatic adjustment system and health care, BRACKET intends to prevent the health problem of bedsores produced by prolonged laying of elderly persons. Sensor data acquisition, automatic adjustment algorithms, and user interaction systems are all part of the overall design.

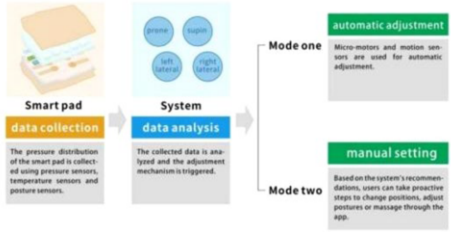

Figure 1. The BRACKET preventive program is depicted schematically.

Figure 1 depicts a schematic of the BRACKET-based preventative technique. The frequent redistribution of body pressure on the mattress is one of the basic measures for the prevention of pressure ulcers, a process that is usually sustained through manual interventions by caregivers eager to change the subject's human body lying posture (HBLP)[11]. However, such interventions confront problems such as time commitment, subjectivity, specific demands, and a real-time aspect, which may result in uneven results, particularly given the difficulty of monitoring at night. As a result, several hospitals have employed automated methods to better utilize human resources in certain of the wards where they are required, which allow for HBLP identification but only allow for limited documentation and do not allow for HBLP treatment.

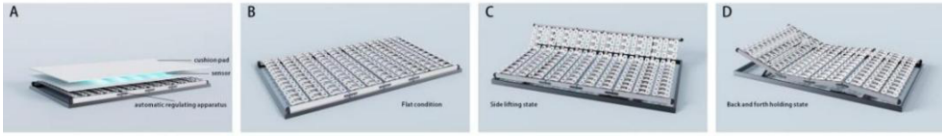

Figure 2. A is the unfolded view of BRACKET appearance and structure, B is the flat state of BRACKET, C is the side automatic adjustment state of BRACKET, and D is the supine adjustment state of BRACKET.

3.1. Design of Smart Pad Hardware

BRACKET is outfitted with a range of sensors to collect data on the elderly's sedentary posture and body pressure distribution. Pressure sensors, for example, are implanted in various locations of the padding to detect the pressure distribution exerted by the old body in real time. In addition, posture sensors are employed to detect the sleeping posture of the elderly in order to establish a foundation for subsequent automatic modification. Body temperature fluctuations can suggest a variety of medical issues.These sensors work in tandem with a variety of temperature sensors within the BRACKET to continuously measure a person's body temperature.

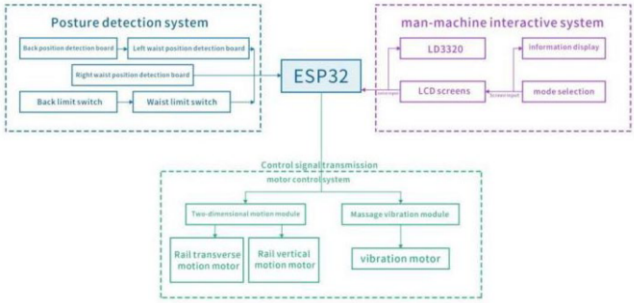

Figure 3. Diagram of the BRACKET system framework.

Principles such as piezoelectric or capacitive changes in pressure sensors are used to evaluate the applied force in pressure sensors for pressure detection, and the data received from these sensors can help assess the user's comfort level, triggering BRACKET to automatically adapt the form. The pressure sensor is utilized in conjunction with posture sensor detecting for the prone posture, while accelerometers and gyroscopes are employed to precisely distinguish different lying postures, triggering stepper motors to automatically modify the prone posture for the user. A thorough examination of these sensor values not only provides consumers with different sleep modes, but also objective measurements for automatic adjustment.To ensure a healthy temperature for the human body, a heating module with adjustable heat options available on the market is used in conjunction with temperature sensor monitoring.

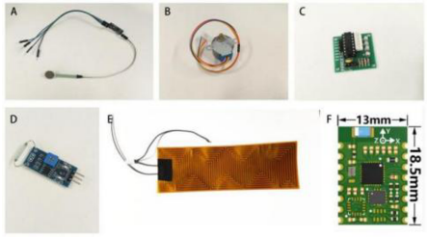

Figure 4. A represents the pressure sensor, B represents the stepper motor, C represents the driver board, D represents the temperature sensor, E represents the heating module, and F represents the attitude sensor.

3.2. Design for automatic adjustment

BRACKET's core is the automatic adjustment algorithm. The algorithm evaluates an older person's sedentary posture and pressure distribution in real time using sensor data, and then adjusts the form of the mat using a specified adjustment technique.

A machine learning algorithm is employed in the BRACKET pose identification session to recognize the user's sedentary pose using transfer learning, a machine learning method that may take a pre-trained model and change its last few layers to specialize to a new task. To accomplish this, a significant number of sedentary posture samples are first collected and classified into categories such as prone, supine, left lateral, right lateral, and so on. The sedentary pose classifier is then generated by selecting a pre-trained deep neural network model and training it on the ensemble tuning issue. The core code for the basic implementation of the auto-adjustment design is shown below.

```
while bed_mat_in_use:
    pressure_data = get_pressure_sensor_data()
    high_pressure_regions = analyze_pressure_data(pressure_data)
    current_position = classify_position(pressure_data)
    if current_position == supine_position:
        if high_pressure_regions exist:
            adjust_bed_mat_shape(high_pressure_regions, reduce_pressure)
    if current_position == lateral_position:
        if high_pressure_regions exist:
            adjust_bed_mat_shape(high_pressure_regions, distribute_pressure)
wait_for_some_time
```

3.3. System for Interaction with Users

To address the demands and preferences of the elderly, BRACKET incorporates a user interaction system. The hardware system is the BRACKET, which includes automatic posture correction as well as health care, and the software system is an application that, when paired with the hardware system, can give customizable settings, data collecting and analysis, and so on. Users can customise and adapt the automatic adjustment approach by entering their comfort preferences, sleep habits, and other information through mobile WeChat apps or smart terminals.

Figure 5. A represents the applet interface, B represents the BRACKET mode selection interface, C represents the user parameter interface, and D represents the personal information interface

4. Experimental Design and Results Evaluation

4.1. Design of an experiment

In order to evaluate the automatic adjustment mechanism of BRACKET, a mixed experimental design was used in this study, combining laboratory tests and real-world tests, with the goal of simulating the situation of elderly people lying down for an extended period of time and comparing the effect of using smart pads versus traditional mattresses. The subjects were randomly assigned into two groups of 30 each: the smart pad group and the regular mattress group. In the experiment, 60 elderly people aged 55 years or older were recruited from the community as subjects. Their health was very stable, and they had no major bedsore issues.

4.2. Technique for testing

The BRACKET's sensor system, which included pressure sensors, posture sensors, stepper motors, and temperature sensors, was installed before to the start of the experiment. The control group received a standard mattress that was likewise outfitted with pressure sensors for comparison with BRACKET. During the experiment, subjects slept on BRACKET and ordinary mattresses for 48 hours. Pressure sensors were utilized to collect data on pressure distribution on mattresses in order to analyze pressure distribution uniformity and to record changes in the subject's body position.

4.3. Experimental setting

The experimental setting is divided into two stages: laboratory testing and real-world testing.Experiments are carried out in a controlled laboratory environment using a simulated mattress. The performance of BRACKET's automatic adjustment mechanism under ideal conditions is the emphasis of this phase. Real-world testing: The subjects will go home with either the smart pad or the control mattress for a two-week real-world test. This phase seeks to assess the actual impact and user experience of

BRACKET in everyday life.

4.4. Data analysis and outcomes

We gathered information on sleep posture, body pressure distribution, and user comments. We conclude that in laboratory experiments, BRACKET's automatic adjustment mechanism efficiently reduces localized pressure in various sleep positions and improves body pressure distribution by comparing data from the smart pad group with the standard mattress group. BRACKET proceeded to optimize the prolonged sleep posture in real-world tests and received favorable comments from the elderly. BRACKET, as seen in the graph, considerably minimizes the risk of bedsores when compared to regular mattresses.

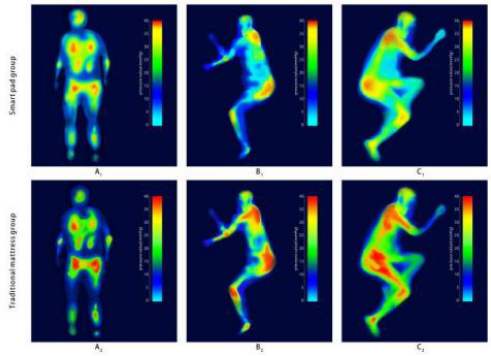

Figure 6. A1 depicts the BRACKET's supine pressure distribution, B1 depicts the BRACKET's left lateral pressure distribution, C1 depicts the BRACKET's right lateral pressure distribution, A2 depicts the conventional mattress's supine pressure distribution, B2 depicts the conventional mattress's left lateral pressure distribution, and C2 depicts the conventional mattress's right lateral pressure distribution.

5. Evaluation and user experience

5.1. User feedback gathering

Qualitative and quantitative user feedback was collected to acquire a more comprehensive picture of older people's experiences and evaluations of the BRACKET. During the real-world testing phase, participants were questioned how they felt about the BRACKET, how comfortable it was, and whether they saw an improvement in their sedentary posture using face-to-face interviews and questionnaires. Users were also asked to review their overall experience. Older persons completed the questionnaires by comprehending the design of this BRACKET, and 60 questionnaires were collected in total.

5.2. Analysis of User Experience

The following user experience analysis results were achieved by collecting and analyzing user feedback data.

Improved comfort:Most seniors reported that the BRACKET is substantially more comfortable than standard mattresses. They claimed that after using BRACKET, the discomfort and pressure they felt when lying down for an extended amount of time were greatly decreased, and their sleep quality improved.

Users are pleased with BRACKET's automated adjustment system, which adjusts the form of the mattress in different sleeping positions, resulting in a more even distribution of localized pressure and lowering the incidence of bedsores.

customizable Settings: Users praise BRACKET's customizable settings, which allow them to tailor the automated adjustment approach to their specific needs.

5.3. Results of the experiments and user feedback

The following findings are reached from the user input and experience analysis in Table 1:The automatic adjustment mechanism of BRACKET may effectively enhance the elderly's prolonged resting posture, alleviate local pressure, and reduce the danger of bedsores. Users are pleased with BRACKET's comfort increase and automatic adjustment effect, and believe that BRACKET improves sleep quality.Users appreciate BRACKET's customizable settings, which may cater to the needs and tastes of many senior individuals.

Table 1: A survey of senior people's attitudes toward the use of smart pads was conducted.

Concern(Please provide a rating from 1 to 5, with 1 being very dissatisfied and 5 being very satisfied)	Average price
1. Would you be happy if you could use this smart pad for the rest of your life?	4.33
2. How do you feel about the Smart Pad's comfort?	4.27
3. Do you think the Smart Pad to be useful?	4.32
4. Are you satisfied with the Smart Pad's functionality?	4.35
5. Do you have faith in the Smart Pad's functioning and the accuracy of the data?	4.23
5. Would you recommend the Smart Pad to other elderly people?	4.28

The success of BRACKET's design concept and automatic adjustment mechanism is supported by user experience and evaluation findings, which improve comfort, improve sleep posture, and reduce the risk of bedsores. However, there is still room for BRACKET to be developed and improved in terms of customizable options and user experience.

6. Future work and constraints

Despite the results of this study, there is still future work to be explored. The range of body position recognition not only focuses on lying classification, but also includes

sitting and semi-recumbent to more comprehensively meet the needs of the elderly in prolonged lying; to achieve personalized and automatic adjustments to personalize the mattress form according to the individual characteristics of the subjects; and to enhance the remote monitoring and control system to better meet the needs of the elderly and to achieve real-time adjustments in a remote manner. Future work will focus on expanding the sample size of subjects to better validate the generalizability of the study results, and simplifying the cost and complexity of the hardware to make the BRACKET system easier to apply in practice and better meet the health needs of the elderly.

The limitation is that the relatively limited sample of subjects does not fully represent the diversity of older adults, which may affect the generalizability of the experimental results.The practical application of BRACKET involves multiple sensors and control systems, which may increase the hardware cost and system complexity, and require more engineering optimization.

7. Conclusions

This study aims to address the problem of pressure ulcers caused by prolonged bed rest in the elderly by using BRACKET to prevent pressure ulcers by automatically adjusting its form to disperse pressure, improving sleeping posture, and promoting blood circulation when the elderly are lying in bed. Evaluation results from experiments and data analysis show that BRACKET has achieved significant results in preventing pressure ulcers and improving prolonged lying posture, which helps to increase the market acceptance of BRACKET. The study has multiple values: an innovative solution to the problem of pressure ulcers, which can be widely used in the care of elderly people who are bedridden for long periods of time; BRACKET improves patient comfort, reduces discomfort, and helps protect privacy. In addition, the application saves professional resources and reduces the burden on the healthcare system; most importantly, the exploration of this technology provides new ideas and insights for the application of smart medical technologies in bedside care and healthcare. Future work will be devoted to optimizing the technological approach to further improve the classification performance and integrate it into rehabilitation care for the elderly who are lying in bed for long periods of time.BRACKET offers a new solution for the prevention of pressure ulcers in the elderly who are lying in bed for long periods of time, and it is expected to play an important role in geriatric care. This product innovation is expected to attract the attention and adoption of medical institutions, nursing homes, home care services, and other organizations, thus providing favorable conditions for the future commercialization of BRACKET.

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