A conceptual design of a modular multifunctional nursing bed for moderately disabled patients

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Abstract. The disabled elderly people are a major part of the overall disabled people in China. The demand for elderly care is growing rapidly. The manual requirements for nursing staffs are also increasing rapidly. Therefore, this situation places a higher demand on rehabilitation products, especially nursing beds. However, traditional nursing beds cannot meet the needs of disabled patients for auxiliary nursing at different stages of rehabilitation. This project proposes a modular multifunctional nursing bed for moderately disabled patients. The nursing bed is modular and uses intelligent technology for multifunctional functions. It can be used in a hospital environment and is designed for different medical stages. The modular multifunctional bed aims to help in patients' rehabilitation and improve well-being.

Keywords: Multifunctional Bed · Modularization · Humanization · Rehabilitation · Human Factors

1   Introduction

The society is aging in many parts of the world, including China [1]. The elderly disabilities are the main part of the disabled in China [2]. Disabled patients need nurses to help them bathe, eat and walk. However, the number of professional nursing staff in China is very small [3]. The rapid growth of the elderly population will lead to an increased burden in elderly care. This situation places higher requirements on health care products. Therefore, there is an urgent need for more solutions to help disabled elderly to carry out their daily routine and in addition provide rehabilitation activities. This will eventually relieve pressure for nursing staffs.

The medical procedure for disabled patients includes three stages namely: diagnosis, treatment, and rehabilitation. The whole procedure is performed on the medical nursing bed [4], requiring disabled patients to stay in bed for a long time. Long-term bedbound can cause the patients' body function to degenerate and may produce complications, such as bedsores [5]. In addition, this situation can even cause psychological problems for the patients [6]. Clinical practice has shown that the physical rehabilitation treatment of long-term bedridden patients is very necessary. Scientific rehabilitation training can gradually restore the motor function of patients [7]. Therefore, there is an urgent need for a solution that can help disabled patients carry out rehabili-

tation training. As the most indispensable medical equipment for bedbound patients [8], medical nursing beds have become the primary choice for innovation and improvement in this research. It is very important to develop a multi-functional intelligent medical nursing bed to meet the urgent needs.

There are several studies on nursing beds in Europe and the United States [9,10]. Representative companies are Devicelink in the United States and Arjo Huntleigh in Sweden. They have all carried out the research and development of nursing bed [9]. The Arjo Huntleigh has developed a nursing bed with bathing function. This nursing bed can offer the bathing function without moving the patient. It not only reduces the workload of nursing staff but also avoids secondary injuries caused while moving the patients [10]. This solution proved the feasibility of modular design and played a certain role in daily care for patients. In general, many scientific research institutions have made many innovations in the research of multifunctional nursing beds. But the research of multifunctional nursing beds is still in the development stage. The nursing beds have broad application prospects and research space. There are more possibilities in assisting moderately disabled patients for rehabilitation or psychotherapy by developing a modular multifunctional nursing bed on this project.

Based on rehabilitation and ergonomics knowledge, this project has designed an intelligent nursing bed solution. The functional structures of the nursing bed have been designed with different function modularity. In this study, different functional modules were analyzed, and an intelligent nursing bed was designed. 'Care+', 'Health+' and 'Warm+' are solutions proposed for different stages of diagnosis and treatment. The purpose of this research is to solve the technical shortcomings of ordinary nursing beds and provide effective care for disabled patients. The difference between the medical bed designed in this project and the single-function medical bed lies in three innovative models that can be changed to meet the different care needs of patients.

2   User Research

The research methods include two parts: (a) Observation of patients using hospital beds in the medical environment to discover the design insights. (b) Interviews with patients and stakeholders on previous bed usage.

2.1   Observation

Researchers visited three hospitals to observe and record the activities of patients, their families, and medical staff using nursing beds in the hospital environment. The observers were two patients, a nurse, and a family member. Patient A, a moderately disabled patient, was hospitalized for about two months due to a fracture of his left foot. Patient B was a mildly disabled patient and used a nursing bed only with the basic functions.

The first stage was to observe the daily nursing activities. Two problems were found based on the observations. First, first time users need to learn how to use the bed from others. The instructions of the bed function are not intuitive. The specific adjustment and operation methods of nursing bed cannot be clearly displayed.

Secondly, the manual adjustment control is at the end of the bed, the patient cannot operate the bed by themselves. Sometimes, fast adjustment by others may cause discomfort.

The second stage was to observe the rehabilitation training process. In this stage, several problems were found. First, patients can only receive simple massage to achieve the initial effect of preventing muscle atrophy. Specialized rehabilitation training was conducted in a rehabilitation room. The patient needed to use a wheelchair to go to the rehabilitation room. During the transfer process, multiple nurses were required to help move the patient. This procedure may cause discomfort and pain to the patient.

2.2　Interview

After the observation, the researchers interviewed patients, medical staffs, and family members to gain their needs on using nursing bed products.

Patients hope to improve the comfort and autonomous control of the nursing bed. During the treatment phase, the patient's family members often sit in a chair nearby to accompany patients. They hope to get better rest during the long waiting periods. From the perspective of nurses, they hope that the nursing bed can help patients turn over and move during the rehabilitation treatment. This can reduce their workload and improve the quality of treatment. At the same time, the nurses also expressed the need that the nursing bed can have some sort of AI function that can help to communicate and guide the patients more effectively. They think this can alleviate the patients' negative emotions. From the doctors' point of view, in the rehabilitation training stage, they hope that the nursing bed can help detect the patients' blood pressure, body temperature, and other general physical signs to improve their work efficiency.

3　Process and Prototype Development

3.1　Concept

The results of user research provide a reference for the concept and prototype development. The study found that stakeholders have different needs for the functions of the multifunctional nursing bed at different stages. In addition to offer basic functions, patients also have emotional needs. The design solution needs to offer the basic functions of the nursing bed, but also need to meet more emotional requirements and medical treatment needs. Therefore, the design goal was to provide users with rehabilitation functions based on the basic functions of nursing beds as well as some entertainment. The conceptual design sketch is shown in Figure 1.
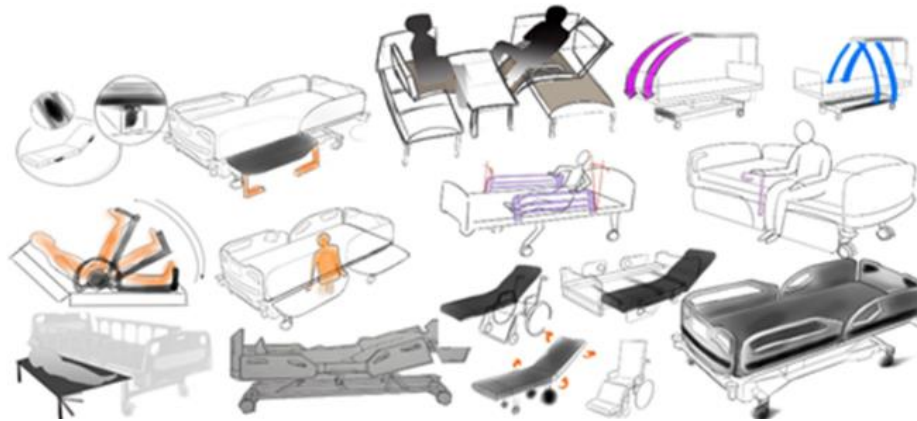
**Fig. 1.** Conceptual sketching

3.2 Cardboard modeling

Based on conceptual design, a cardboard prototype of the multifunctional nursing bed was developed, and the feasibility of structure transformation was verified. It is shown in Figure 2.

Fig. 2. Cardboard testing

3.3 Prototype developing

The shape, size, and surface of the prototype have been repeatedly evaluated and modified. Figure 3 shows the prototype model in the iterative design process.
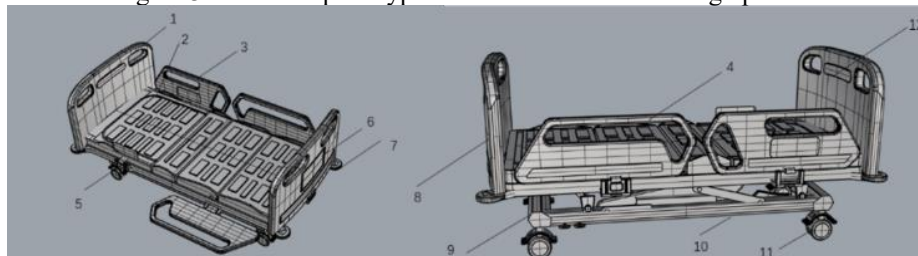
Fig. 3. Prototype developing

This design proposes three modular design solutions, Care+, Health+, and Warm+. Care+ model takes affective design as the starting point to solve the problems of inconvenient washing on the bed and getting out of bed at night. It adds a foldable guardrail and a bedside display screen, making it easier for family members and nurses to take care of patients. Health+ mode adds a rehabilitation exercise module that is different from the current market competitors to help disabled patients perform lower limb rehabilitation training. Warm+ mode adds a simulated sunbathing module, using the built-in air circulation system and blind lighting design. The design reduces the labor intensity of nursing staff, improves the comfort of patients.

4　　Evaluation of nursing bed design

Medical products have strict industry standards. It is necessary to apply ergonomics knowledge in the structural design of the nursing bed. Human factors data can be obtained and analyzed using the anthropometric method.

In this paper, the design index of multifunctional nursing bed is determined by referring to the relevant standards such as "Medical electrical equipment-Part1: General requirements for safety" [11]. It is including size index, position adjustment index, and bearing index. According to the international medical equipment general standard and referring to the relevant dimensions of the existing nursing bed in the market, the overall dimension of the nursing bed is determined as 2100mm × 1000mm × 600mm. The movement angle of Health+ model during the first 0° to 30° and the last 20° to 90° hash 5° to 10° increment respectively [12]. The multifunctional nursing bed sets the movement angle of the leg bending mechanism according to the above index. The final prototype is shown in Figure 4 and Figure 5.

Fig. 4. The final prototype of Care+

Fig. 5. The final prototype of Health+ and Warm+

To sum up, the modular multifunctional nursing bed design solution can offer three models which have different functions. This project can improve the needs of moderately disabled patients at different stages in the treatment process. Even more, this study pays attention to the psychological feelings of disabled patients. By using the modular multifunctional nursing bed, patient's daily life can be more easily and comfortably, thus improving self-confidence and dignity.

5   Conclusion

This research focuses on the design of nursing beds for moderately disabled patients to improve the user experience of the treatment with moderately disabled patients. These results may help formulate design standards for nursing bed products for moderately disabled patients. According to the interview, patients mentioned that this improvement can inspire them to have a positive attitude on their rehabilitation.

The limitation of this research is that the design is still in the conceptual design stage. The product prototype design and evaluation will be carried out in the follow-up research. Smart medical products are needed in smart medicine as the society is rapidly aging and there is a continuous lack of nursing staffs.

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