The Design of Hemiplegia Rehabilitation Equipment Based on Contextual Inquiry

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Abstract. Rehabilitation equipment is the most important hardware facilities in recent medical field. The treatment methods led by medical rehabilitation instruments have been widely promoted. Besides, the study of elderlies’ hemiplegia rehabilitation has become hot issues. However, the function of rehabilitation instrument on the market is simple. How to carry out design innovation on the rehabilitation equipment has become a difficult problem to be overcome in research. Hence, this paper clearly points out the goal that finish an improved design based on existing rehabilitation equipment, which is study the elderlies’ hemiplegia rehabilitation by Contextual Inquiry and observation. According the study, we arranged results of key events and five working models. Then, we did an improved design and got a conclusion by the study results.

1. Introduction

1.1. Research background and motivation

With the development of society and improvements of electronic technology, People's rehabilitation therapy has changed from simple rest and medication to many aspects of rehabilitation treatment and methods. The use of instruments for rehabilitation plays an increasingly important role in modern medical treatment. In recent years, the medical rehabilitation instrument as the leading treatment method has been widely promoted with the development of science and technology, hence, apply the technology to help people recover health has become the focus of current medical work.

Central nervous system damage leads to central spasm, and the regulation of high-level motor regulation inhibits the regulation of the low-level motor center of the spinal cord, leading to the complete release of the primitive functions of the lower-level central nervous system. The brain cannot regulate it, and the influence of the external environment causes the motor cycle to be constantly excited. The affected parts of the organs cause increased muscle tone, muscle spasm, joint contracture and stiffness [1]. Due to the damage of the central nervous system, the reflection transmission is abnormal. The body's motor coordination control ability is lost, and the sense of ability to the outside environment is lost, so that the balance function of the human body is affected, resulting in sitting and standing instability.

Rehabilitation equipment is specific equipment in medical field, it belongs to comprehensive technology and plays a vital role in diagnosis, treatment and recovery. Besides, rehabilitation equipment also has positive effects on curing physical illness caused by various reasons as an adjuvant therapy. However, with the increase in the number of human diseases and growth of drug resistance,
medical rehabilitation equipment technology has shown a backward trend. Innovating it has also become the focus of modern research. The main function of rehabilitation equipment is to maintain joint mobility, enhance muscle strength, muscle endurance and coordination [2].

Excellent rehabilitation instrument design is beneficial to improve the blood status of patients with hemiplegia in neurosurgery, improve motor function and daily living [3-5].

1.2. Research purpose
Improving the design of the lower limb rehabilitation training equipment for the elderly based on the existing products.

1.3. Research problems
This paper firstly hopes to find out the use groups and using principle of the rehabilitation equipment. Then, the paper attempts to use Contextual Inquiry [6,7] to understand why rehabilitation equipment has effect on the patients’ recovery. Then observe that during the patient’s use of the instrument, what state the family is. Last, the research wanders whether the patients can finish the training independently without families’ companion.

2. Research methods
Using Contextual Inquiry (Holtzblatt & Jones, 1993) which performs the observation and interview at the user’s workplace simultaneously [8]. Getting context by the method can help design the product which support user’s daily activities. It is easy to find details and difficulties during the user’s working time.

This paper observed and interviewed 15 patients with hemiplegia, 10 patient’s family and 5 doctors, noted the records. We interviewed 30 interviewees 30 minutes each person in site. Questions covering 5 research directions, each direction with 4 to 6 questions on site. Interviewer recorded contexts and data by noting and recording. Observation focused on the patient’s general training time length, training methods, degree of difficulty and security status on rehabilitation equipment. Contextual Inquiry focused on the security problems in equipment, family, doctors and surroundings during the patient’s training process.

Interviewers recorded on sites and completed records after interview. Then, numbering each interviewee and making succinct conclusion. The recorded contexts were classified and researched in 5 working models [9].

2.1. Five working models
The Cultural Model reveals the harmonious relationship between patients and families, patients and doctors, families and doctors.

The Tool Model shows how to use the rehabilitation equipment, whether the equipment is safety and convenient for the patients to operate. Whether the recovery achieves the desired effect by using the rehabilitation equipment.

The Physical Model shows the patient with equipment in physical environment and the safety issues surrounding the patient in using the equipment.

The Task Model shows the patient in performing the rehabilitation process, whether each step can achieve the desired purpose of training, recovering and using.

The flow Model depicts the rehabilitation equipment that is safe and smooth to perform each necessarily communication and cooperation in safety and convenient aspects.

3. Research results
3.1. Key event results
According the mentioned methods, we interviewed 30 research objects (15 patients, 10 families and 5 doctors), got the related interview records. Then, organized and analysis the records. Finally, the key
events and key time which got from the interview were classification recorded in the form of tables. Results are shown in Table 1 Key events results.

Table 1 Key event results

| Key Event | Description | Findings | Advice |
|-----------|-------------|----------|--------|
| Patients can’t lean on the safe belt | The safe belt can’t provide enough security for patients, so they prefer grip the table board to lean on safe belt. | Because of design problems, safe belt for ordinary elastic cloth can’t provide security for patients. | Offering a foothold or protection for patients. |
| When the patient uses it, he must be accompanied at all times. | The safety of the device is low, the patient and family cannot be assured. | The equipment is no able to give the patient enough support and fixation. | The equipment can be used separately for patients. |
| Patients grip the table board tightly. | Patients are afraid of falling when using the device, and it is very laborious to grab the board. | Desktop design has certain defects, just a smooth board without any supporting part. | Providing a supporting part on the desktop for user. |
| User’s hands lean on the table board constantly, it is an uncomfortable posture. | Low safety factor leads to the uncomfortable operation. | The table board is fixed on the stable angle, patients are unable to adjust the table board in a comfortable angle. | Providing certain support for patients to finish training. |
| Patients’ upper body leaning forward because of insufficient support, families have to help them adjust posture. | It’s hard for patients with hemiplegia stand without back support. | Because of the patients with hemiplegia, it is necessary to provide assistant part for them to finish training. | The equipment with supporting part to stable the patients’ upper body when they training on it. |
| When adjusting the pedal angle, the patient needs to leave the instrument first. Besides, angle choice is limited. | The knob which adjust the angle was designed on the bottom of the equipment, most patients has the difficulty to twist the knob. | Jagged design limited the angle choice, it leads to the discontinuous angle choice, the knob designed in an unreasonable position. | Optimizing the adjusting system, positioning the knob on the reasonable position where user can touch when they standing on the pedal. |

3.2. Five Working Models
Model 1: The Physical Model
As Figure 1 shown, the glasses of doctors’ office are fully transparent. This design is convenient for doctors to observe the patients’ recovery state and training process.

**Model 2: Information Ideas Flow Model (Between interested parties)**

As Figure 2 shown, the patients trust their families certainly. Families will help them finish the recovery training, besides, families also accompany the patients all the time to avoid accident happened during the rehabilitation.

Doctors usually taught families to use the equipment, as how to adjust the equipment. Just as the Physical Model shown, doctors can observe the patients’ training process, hence, families don’t worry too much about the security problems.

Most patients semi-trust doctors, they trust doctors because of their professional guidance, however they are doubt about whether doctors can find they troubles in time when doctors in busy. On one hand, doctor guide patients to recover from illness, patients trust doctors’ profession. But compared to patients’ families, doctors are unacquainted, if their relations absence, elderly patients sometimes
cover up their problems because they afraid to trouble doctors. This phenomenon results from elderlies’ self-respect.

Model 3: The Task Model

### Table 2 The Task Model

| Action                | Context                        | Steps                        | Problems                                           |
|-----------------------|--------------------------------|------------------------------|----------------------------------------------------|
| Stand on the equipment| Standing on the equipment with relations’ help. | Stand on the equipment Strap the safe belts Adjust the pedals | it is trouble to adjust the pedal angle. |
| Recovery              | Stand on the pedal             | Standing on the pedal for about 30 mins. | Lack of security Leaning on table board is tired Boring process The distance between two table boards is too close. |
| Leave the equipment   | Leaving the equipment with relations’ help. | Release the safe belt | |

As Table 2 shown, this paper divides The Task Model into 3 parts, stand on the equipment, recovery and leave the equipment. We found that relations accompany the patients all the time. First, relations have to help patients stand on the equipment, strapping the safe belt on their back. Second, patients have to repeat the stand and leave the equipment process because of the knob designed on the bottom of the equipment. This tedious operation result that patients seldom adjust the pedal angle which is suitable for themselves. Third, the oversimplified safe belt cannot provide enough support for patients, it results them afraid of falling from the equipment, so they have to lean on the table board tightly. This action will waste energy with doubt. Fourth, when patients standing on the equipment for recovery, they were unable to do other things, this process is boring. The distance between two table boards is too close.

Model 4: The Tool Model

As Figure 3 shown, this is a Schematic diagram of equipment, ①Table Board, ②Safe Belt, ③Pedal. The distance between the two table boards is about 50 centimeters. This length is unsuitable for two patients stand face to face. Due to the areas limitation, when patients put hands on the table, there is nowhere for them to put their private good such as towel, cup and phone.

The most important problem of pedal is knob, it is unrealistic to repeat stand and leave the equipment, moreover, most people don’t know how to adjust the pedal angle, they choose to accept the uncomfortable angle, it will do harm to their ankles. Block type design is unreasonable.
Model 5: The Cultural Model (Attitude to key events)

![Cultural Model Diagram](image)

**Figure 4. The Cultural Model**

According to observation, interview and research, the Cultural Model is shown in Figure 4. The research found that patients actually know little about the equipment they used. They rely on the equipment because they think it will help them recover from the illness, however, they have no trust on the equipment. They seldom have positive attitude on the equipment. The ideal situation is that patients have a positive relation with the equipment, then, they are willing to recover on it.

Elderlies worry they will be burden of their children, they hope to prove themselves. Under these circumstances, the elderly patients with miplegia always have large pressure. They are more likely to feel that they are the burden of others because of the illness. The problem will be infinitely magnified if they found they lose the ability to training independently. Meanwhile, pressure and worries pour out.

From the perspective of family, they will never leave the elderly patients training alone. Doctors may not take care of each patient carefully due to the number of patients.

### 3.3. Analysis and Summary

Analyzing the statistical results come from tables and models

1. Patients worry about the equipment’s security issues, so a more reasonable structure will bring them more feeling of security when they use the equipment.
2. The table board on the equipment needs to assembling handgrip to make sure balance of patients’ body.
3. The design of pedals should consider patients’ personal demands. Optimizing the adjustment method is necessary.
4. Taking account in the long time on the equipment causes boring, certain entertainment facilities are able to attach in the equipment, but it is not necessary.

In summary, improved design existing in the redesign of safe belt on back, redesign of table board and the structure design of pedal.

### 4. Design Innovation

4.1. Attaching pads on the back and the legs.
Differences: before design, Lack of security.
            After Design, increasing security.

4.2. Adjustable height handrail and leg braces
Differences, before design: patients’ upper body leaning forward and hands gripping the table board because of insufficient support.
            After design, providing a handrail for patients to put their hands and they can adjust the height according to their personal requirements. The height of whole equipment could be adjusted to cater to patients’ height.

4.3. Changing the material of table into more soft material and adding borders around the table.
Differences: before design, wooden is hard for elderly patients and smooth surface personal belongings are easy to slip from the smooth surface.
            After design, increasing the comforts of the table, borders protect the belongings from slipping.

4.4. Adjusting pedal from manual adjustment to automatic adjustment, controlled by interface.
Differences: before design, manual adjustment is complicated, patients can’t finish the action independently. Besides, angle selection is not smart enough.
            After design, automatic adjustment is easier for patients to select their suitable angle, they can stand on the pedal and adjust the pedal angle by operating on interface. This design makes them choose angle directly and quickly. They can also adjust the angle by themselves.

4.5. Adding a display to the equipment.
Differences: before design, long time training brings boring and discomfriture.
            After design, three advantages. First, entertainment eliminates boring during the training, it makes the training become more easily. Second, timing function, this will remind patients to pay attention to training time, creating a normative training plan. Third, adjusting angle precisely can be realized by controlling the virtual button on display. The value shows more intuitive feelings.

4.6. Adding emergency button.
Differences: before design, doctors and relations have to pay attention on the patients all the time, they constantly asking patients for feedback.
            After design, connected with doctors’ computers, doctors can receive the information at any time. Emergency button can make patients call for help immediately when they feel uncomfortable during training.

5. Conclusion
This paper is based on the increasing number of elderly patients with hemiplegia and the important of using medical equipment products for rehabilitation to interview by Contextual Inquiry. According to the relevant information about the ankle rehabilitation equipment, we confirm the Human Factor (Users) is patients with hemiplegia, the research purpose is designing an ankle rehabilitation equipment which is more convenient and efficient for patients. From God’s perspective, we set ideal state and use it to minus the present state. In this way, the preliminary questions came out. After Contextual Inquiry and observation, further problems were excavated such as pedal angle problem, safe belt problem and table board problem, etc. Last, in trust design of present product, a new ankle rehabilitation equipment was designed based on the improvements of mentioned problems.
            This paper excepts the research methods which Contextual Inquiry and using God’s perspective minus present state to find problems can provide a solution for other products’ improved design.

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