Research and evaluation of functional clothing for patients with paraplegia of both lower limbs

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Abstract. Because of the particularity of the body, the clothes of ordinary people are not suitable for paraplegia patients. In this paper, by means of questionnaire survey and incision experiment, a functional garment is developed for patients with paraplegia of both lower extremities, which integrates the structural fitness and convenience of wearing and taking off. Moreover, the functional clothing was evaluated by referring to the convenience evaluation system and combining with the subjective evaluation method. The results showed that the structural fitness of the functional garments was improved, especially the tension of the elbows and knees was significantly reduced. In addition, the convenience of wearing functional pants was also significantly improved: participants' participation in the three ADLs was significantly increased when wearing functional pants, all of which were 100%. The time taken to complete three ADLs in functional pants was also reduced, among which the replacement of diapers was the most efficient, reducing the time by 70.39%.

1 Introduction
Paraplegia is a severe neurological disorder caused by spinal cord injury, resulting in motor impairment and loss of function below the injury level. Paraplegia caused by spinal cord injury below the third thoracic vertebra is paraplegia of lower limbs. Due to the particularity of their bodies, ordinary clothes can no longer meet their clothing needs. In particular, the convenience of clothing is directly related to the quality of life of paraplegia patients.

There are already five American companies and one Canadian company selling disabled people's Clothing through e-commerce, namely "Adaptive Clothing", with a relatively complete category of Clothing. However, the development of clothing for special groups in China is still at the theoretical and research level, lacking of systematic research, development and production system. At present, the research on clothing for the disabled mainly focuses on the comfort of fabric, fit of structure and convenience of wearing and taking off. However, no scholars have specifically studied the clothing for paraplegia patients with lower limbs.

In this paper, according to the results of questionnaire survey, functional design was carried out for patients with paraplegia of lower limbs. The incision experiment method was adopted to conduct structural research, and a functional garment integrating structural fitness and ease of wear and tear was developed. The functional garments were evaluated comprehensively based on the convenience of wear and tear evaluation system.
2. Methodology

2.1 Questionnaire Survey
In order to further understand the current situation and special needs of the patients with bilateral paraplegia, a questionnaire survey was conducted in this project. Through the questionnaire survey, it is found that patients have higher requirements on the softness and warmth of fabrics in terms of fabric comfort. The structural problems are mainly the tight chest, back and elbows in the sliding wheelchair, as well as the tight waist and knees in the trouser suit in the sitting position, and the serious downward movement of the back waist and foot mouth line. In terms of convenience, most patients prefer to open the front crotch, and select zipper or Velcro as connectors. In addition, 81% of patients need to wear diapers, so trouser suits should also be designed to facilitate changing diapers.

2.2 Functional clothing design scheme
According to the research results, the style design of functional clothing for patients with paraplegia of lower limbs was carried out (see Figure 1). To make it easier for both the patient and his caregiver to put on and take off the jacket, the jacket is fully open in the front and back and is connected by a zipper, while the side-sewn zipper is designed to alleviate the problem of a tight waistline. To prevent cuff wear and ease garment cleaning, last week's cuff was fitted with detachable sleeves. The lower garment is a multi-opening trouser suit, the side slit opening is mainly for the convenience of patients to put on and take off, while the inner slit zipper is for the convenience of patients to change diapers.

![Figure 1 Design drawing](image)

2.3 Garment incision experiment
Incision experiment is to study the relations of garment deformation and body movement experiment method, is the key part in experimental clothing set appropriate opening size, make the costumes subjects to complete different body movements, changes in the human body in amount of open clothing incision, and analyze the linear relationship of opening amount and the relaxation of the clothing, clothing model based on the actual demand, calculate the size of the relaxation of the each part of the garment.

In this experiment, three common movement changes in the activities of patients with paraplegia of the lower extremities were taken as experimental movements. The C-shape intermediates closest to the patient's body shape were selected as subjects, and the basic jackets and trousers of 160/88C (female) and 170/100C (male) were taken as research objects. The sizes of the experimental clothing were shown in Table 1.

| position | Shoulder (S) | chest (B) | clothes length(CL) | Sleeve length(SL) | Waist (W) | Hip (H) | Trouser length (TL) |
|----------|--------------|-----------|--------------------|-------------------|-----------|---------|---------------------|
| M        | 46           | 116       | 65                 | 62                | 100       | 106     | 102                 |
| F        | 39.2         | 104       | 60                 | 53                | 86        | 104     | 93                  |
2.4 Evaluation system for convenience of wear and tear based on motion research

Action research is also called "method research" or "working method design". Its main content is to find and seek the most economical and effective working method through various analytical means. In the field of clothing research and development, it is used to measure the convenience of operation of functional clothing by analyzing the difficulty of movement completion.

The convenience evaluation system is a three-level comparison principle proposed by Wu Daiwei based on movement research. The order of the factors considered in the three-level comparison principle is the sum of the convenience performance scores of all THE ADL items, the degree of autonomy of participating in each ADL and the total time of all the action items of participating in each ADL. Where, the calculation formula of degree of autonomy L is:

$$L = \sum_{i=1}^{n} \text{§} * K_i$$

In the formula, K is a variable. When the action is voluntary, K=1; otherwise, K=0.

§ refers to the difficulty coefficient of each decomposed action in the total activity, §= the difficulty value/the sum of all movements of the ADL.

This evaluation experiment mainly adopts the second and third principles of the wear and tear evaluation system, and evaluates the convenience of wear and tear of functional trousers and the looseness of jackets by combining subjective evaluation method and comparative analysis method. The experimental clothing was functional clothing for patients with paraplegia of both lower extremities, and the control clothing was ordinary jacket and pants (see Figure 2).

![Figure 2 Experimental clothing (left) and control clothing (right)]

In this experiment, adLS related to patients’ wearing and taking off clothes were selected, namely changing clothes, using toilets and changing diapers. The activities of using toilets were mainly aimed at patients who did not use diapers. The three ADLs are decomposed into actions (see Table 2), and the completion time of each ADL is equal to the sum of the completion time of each action, namely, the completion time of changing clothes: $t = t_1 + t_2 + \ldots + t_6$.

| ADL project | Purpose | Action decomposition | Time consuming (s) |
|-------------|---------|----------------------|-------------------|
|             |         |                      | experimental      | contrast          |
|             |         |                      | clothing          | clothing          |
| Dress and undress | Wear pants | Put on left pants-leg | $t_1$ | |
|               |         | Put on right pants-leg | $t_2$ | |
|               |         | Draw the gears       | $t_3$ | |
|               | Take off pants | Take off the archives department | ... | |
|               |         | Take off your left pants-leg | $t_5$ | |
|               |         | Take off your right pants-leg | $t_6$ | |
| Go to the toilet | Take off pants | Take off the gears | ... | |
|               |         | Draw the gears       | ... | |
|               |         | Take off the gears   | $t_4$ | |
|               | Wear pants | Put on left pants-leg | ... | |
|               |         | Put on right pants-leg | ... | |
|               |         | Draw the gears       | ... | |
|               | Take off pants | Take off left pants-leg | ... | |
| Change the diaper | Take off pants | Take off right pants-leg | ... | |
|               |         | Put on left pants-leg | ... | |
|               |         | Put on right pants-leg | ... | |
|               |         | Draw the gears       | ... | |
In addition to the objective evaluation index, this experiment also needed to subjectively evaluate the wearing difficulty $\varepsilon$ and the looseness of the jacket. The subjective evaluation scale is shown in Figure 3. The $\varepsilon$ is smaller, the convenience of clothing will be better.

![Subjective evaluation scale for the degree of penetration difficulty](image)

(a) Subjective evaluation scale for the degree of penetration difficulty

![The subjective evaluation scale of tightness](image)

(b) The subjective evaluation scale of tightness

### 3. Data analysis and results

#### 3.1 Analysis of opening volume

1. **Ideal relaxation amount for each part**
   
   First, the average value of the three experiments under each action of each part was calculated. In order to satisfy the activity slack of various possible movements of human lower limbs, the maximum opening of the three movements of lower limbs was selected when determining the opening amount, which was expressed as a positive number. In order to meet the patient's normal dress, the minimum amount of overlap among the three body movements was selected and represented by a negative number.

   Taking into account the differences of different body shapes, the data in the table are represented by the percentages of the sizes of various parts of the clothing, and the percentages of the added volume are calculated based on the sizes of the clothing used in the experiment in Table 1. The ideal looseness of tops and trousers is expressed as a percentage (see Tables 2 and 3)

| Clothing parts | Chest | Back | The elbow | Hem before | Hem back |
|----------------|-------|------|-----------|------------|----------|
| M              | 2.58%B| 3.44%B| 2.74%SL   | -4.61%CL   | 10.77%CL |
| F              | 2.88%B| 3.84%B| 3.20%SL   | -5%CL      | 11.67%CL |

| Table 4 Percentage of ideal relaxation amount in each part of trouser suit (%) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Clothing parts  | The waist       | The knee        | Hip waist       | Popliteal fossa |
| M               | -4.90% TL       | 1.96% TL        | 6.86% TL        | -3.92% TL       |
| F               | -5.37% TL       | 2.15% TL        | 8.60% TL        | -4.30% TL       |

The main openings of the coat can be seen in the front chest, back and elbows. The vertical opening of the lower part is small, the horizontal opening is mainly concentrated in the knee and hip, and the overlap is mainly in the waist, abdomen and popliteal fossa.

2. **Garment revision**

   According to the experimental results in section 2, the garment sample was modified. The top modification scheme (see Figure 4) was mainly to add 2cm pleat at the back, 1.5cm wider at the front chest, 1.7cm wider at the sleeve midline, and to modify the armhole line.
The structural modification scheme of trouser suits (see Figure 5) is mainly that the front piece is 5cm in the waist and abdomen, 5cm in the crotch line, and 3cm in the knee side seam. The rear buttocks are spread 7cm in the posterior crotch line. The longitudinal looseness of the front and rear slices was increased at the midline according to the experimental opening.

3.2 Subjective tightness of various parts of the jacket

First, the subjective tightness of each part was averaged (see Table 5). It can be seen that the tightness of the back and elbows of the control clothing is obvious, while the subjective looseness of the experimental clothing is increased, so the structural fitness of the functional clothing is improved. From the distribution diagram (FIG. 6), it can be more intuitively seen that compared with the control group, the tightness of all parts of the experimental group was significantly reduced, especially the tightness of the elbows was greatly improved, and the tightness of the back and front chest was also improved.

| Parts       | Front chest | After back | Elbow       |
|-------------|-------------|------------|-------------|
| The contrast group | 0.07±0.29   | -0.31±0.35 | -0.79±0.25  |
| The experimental group | 0.59±0.14   | 0.87±0.29  | 0.99±0.21   |
3.3 Subjective difficulty values of each ADL

First, the difficulty values of each decomposition were averaged for 12 subjects, and the difficulty coefficients of different ADL movements were calculated according to the formula, and whether each decomposition could be completed independently when patients wore different pants (see Table 6).

![Figure 6: Distribution of subjective tightness of the coat](image_url)

**Table 6** Subjective difficulty values of various decomposition actions of trousers

| ADL project | Purpose       | Action decomposition | $\varepsilon$ | Whether to participate (K) |
|-------------|---------------|----------------------|---------------|---------------------------|
|             |               |                      |               | Experimental trousers      | Contrast trousers       |
| Dress and undress | Wear pants   | Put on left pants-leg | 3.2           | 0.147                     | 1                        | 1                        |
|             |               | Put on right pants-leg| 3.5           | 0.161                     | 1                        | 1                        |
|             |               | Draw the gears       | 4.8           | 0.221                     | 1                        | 0                        |
|             |               | Take off the archives department | 4.6 | 0.212 | 1 | 1 |
|             | Take off pants| Take off your left pants-leg | 2.9 | 0.134 | 1 | 1 |
|             |               | Take off your right pants-leg | 2.7 | 0.124 | 1 | 1 |
| Goto the toilet | Take off pants| Take off the gears | 4.6 | 0.489 | 1 | 1 |
|             | Wear pants    | Draw the gears       | 4.8           | 0.511                     | 1                        | 0                        |
|             |               | Take off the gears   | 4.6           | 0.212                     | 1                        | 1                        |
|             | Take off pants| Take off left pants-leg | 2.9 | 0.134 | 1 | 1 |
| Change the diaper | Take off pants| Take off right pants-leg | 2.7 | 0.124 | 1 | 1 |
|             |               | Put on left pants-leg | 3.2           | 0.147                     | 1                        | 1                        |
|             | Wear pants    | Put on right pants-leg | 3.5           | 0.161                     | 1                        | 1                        |
|             |               | Draw the gears       | 4.8           | 0.221                     | 1                        | 0                        |

According to the formula $L = 1^*K_1 + 2^*K_2 + \ldots + n^*K$ calculates the degree of participation in each ADL (see Figure 7). As can be seen from the figure, when the subjects completed the activities of changing clothes and changing diapers, the participation degree of the subjects wearing contrast pants was 77.8%, while the participation degree of the subjects participating in the activities of going to the toilet was only 49.8%. However, the participants' participation in all ADL was 100% when wearing experimental pants. Therefore, the subjects can complete all THE ADL independently when wearing the experimental trouser suit, and their autonomous living ability is greatly improved.
3.4 Each ADL takes time
The average time of each decomposition was calculated, and the total time of each ADL was calculated (see Table 7). It can be seen that the time spent on completing the three ADLS in the experimental pants was reduced, among which the time spent on changing diapers was reduced to 70.39%, and the time spent on toilet activities only decreased by 33.17%.

| ADL project          | Time consuming (s) | Percentage decrease in time (%) |
|----------------------|--------------------|---------------------------------|
|                      | experimental pants | Contrast pants                  |
| Dress and undress    | 53.66              | 100.96                          | 46.85                          |
| Use the toilet       | 33.29              | 49.81                           | 33.17                          |
| Change wet urine     | 29.92              | 101.05                          | 70.39                          |

4. Conclusion
In this paper, a questionnaire survey was conducted to investigate the clothing requirements of patients with paraplegia of both lower limbs. According to the research results, a functional costume was designed.

In order to increase the structural fitness of the garment, the incision experiment was carried out, and the opening amount was analyzed to obtain the ideal relaxation amount of different parts. The structure of the garment was modified according to the ideal amount of relaxation, so that the upper garment could meet the patient's loose movement when pushing the wheelchair, and the lower garment could meet the structural fitness of the sitting position. At last, the tightness of the jacket was evaluated by subjective evaluation method. According to the results of comparative analysis, compared with the control clothing, the tightness of the jacket was greatly improved, especially the tightness of the elbow was significantly reduced.

Finally, the convenience of wearing and taking off was evaluated by referring to the system. According to the evaluation results, when the subjects wore functional pants, the participation degree of all ADL was 100%, and the autonomous living ability was greatly improved. In addition, the time to complete all ADL when wearing functional pants was reduced, including the time to change diapers decreased by 70.39%, the time to dress and undress decreased by 46.85%, and the time to go to the toilet decreased by 33.17%. Therefore, the convenience of wearing and taking off functional trousers was significantly improved, especially in the change wet urine activities, the convenience of wearing and taking off was greatly improved.
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