

구형 디지털 손가락 힘측정장치를 이용한 재활정도 판단 방법

Judgment Method of the Rehabilitation Extent using a Spherical Type Digital Finger Force Measuring System

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This paper presents the judgment method of the rehabilitation extent using a spherical type digital finger force measuring system (SDFFMS). Stroke patients can't use their fingers because of the paralysis of their fingers, but they can recover with rehabilitative training. The SDFFMS has been already developed by Kim (Author of this paper),⁷ and the finger grasping forces of normal people and stroke patients could be measured using it. But the SDFFMS could be not used to judge the extent of their rehabilitation, because the judgment method using it is not yet developed. In this paper, the characteristics tests for the grasping forces of normal persons and stroke patients were performed using the SDFFMS, and the judgment method of the rehabilitation extent was developed using the results. The tests confirm that the rehabilitation extent of stroke patients could be judged using the developed judgment method.

Key Words: Rehabilitation Extent (재활정도), Spherical Type Digital Finger Measuring System (SDFFMS) (구형 디지털 손가락 힘측정장치), Finger Grasping Force (손가락 잡는 힘), Finger Rehabilitation (손가락 재활)

1. Introduction

Recently, the number of stroke patients with finger paralysis has been greatly increasing, and the patients can't use their fingers. Their fingers can be recovered with rehabilitative training, and the rehabilitation extent can be judged by pulling a hook, and grasping a cylindrical object, a spherical object and a plate. At present, most hospitals use cylindrical objects, hooks, plates and spherical objects which can't measure finger

grasping forces of the patients. Therefore, doctors can only estimate roughly the rehabilitation extent by touching and watching the grasping and pulling actions of patients' fingers.

The developed finger force measuring system¹⁻⁶ with one-axis force sensor can only measure the finger force applied by two fingers (thumb and forefinger) or three fingers (thumb, forefinger and middle finger). Also, the spherical-type digital finger force measuring system with six-axis force/moment sensor⁷ could accurately measure

the finger grasping force of normal people and stroke patients. But the finger force measuring systems couldn't judge the rehabilitation extent of stroke patients. Therefore, the judgment method of the rehabilitation extent for stroke patients' fingers should be developed.

In this paper, the characteristics tests for the grasping forces of normal persons were performed by using the SDFFMS,⁷ and the judgment method of the rehabilitation extent for stroke patients' fingers was developed by using the results. Also, the finger grasping forces of stroke patients were measured by using the spherical type digital finger force measuring system (SDFFMS), and the results were applied to the judgment method of the rehabilitation extent.

2. Spherical type digital finger force measuring system (SDFFMS)⁷

2.1 Finger force measuring principle of spherical object grasping

Fig. 1 shows the finger force measuring principle of a spherical object grasping. If the fingers (thumb, forefinger, middle finger, ring finger and little finger) apply force to the six-axis force/moment sensor in two hemispheres as shown in Fig. 1, the SDFFMS measures finger forces from the six-axis force/moment sensor simultaneously, and the combined force (finger grasping force) can be calculated as equation (1).

$$F = \sqrt{(Fx)^2 + (Fy)^2 + (Fz)^2} \quad (1)$$

2.2 The SDFFMS⁷

The SDFFMS has been already developed by Kim (Author of this paper)⁷ as shown in Fig. 2. The Fig. 2 (a) and (b) show the six-axis force/moment sensor fixed to the inner part of hemisphere and the SDFFMS respectively, and it is composed of the spherical object with the six-axis force/moment sensor and high-speed force measuring device (HSFMD). The spherical object has two hemispheres, and the upper fixture block of the six-axis force/moment sensor is fixed to the inner of the upper hemisphere, and the lower fixture block of the sensor is fixed to the inner of the lower hemisphere. The diameter of the spherical object is $\phi 68\text{mm}$, and the gap between the upper hemisphere and the lower hemisphere

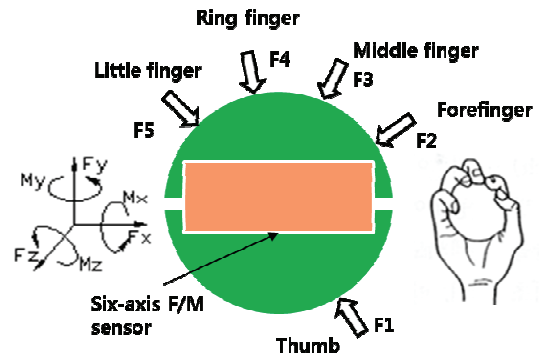
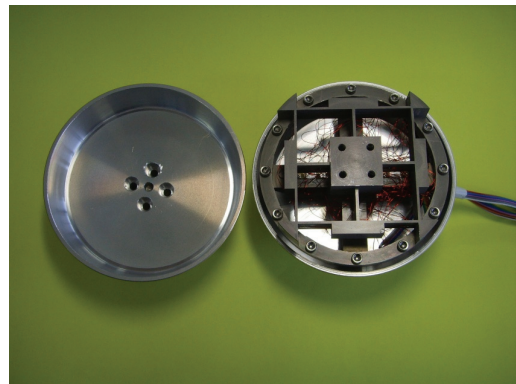
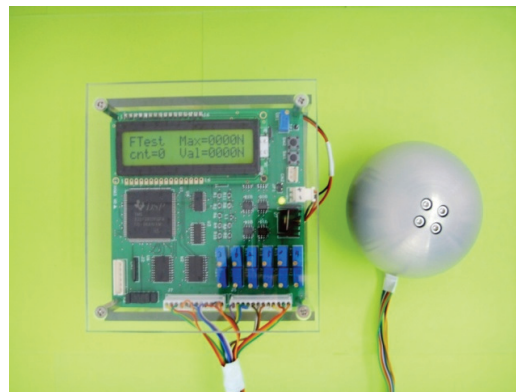


Fig. 1 Finger force measuring principle for gripping a spherical object



(a) Hemisphere and the sensor



(b) SDFFMS

Fig. 2 Spherical type digital finger force measuring system (SDFFMS)

is 1.5mm. The six-axis force/moment sensor is used to measure the finger grasping forces of normal people and stroke patients. The rated capacities of the six-axis force/moment sensor; Fx sensor, Fy sensor and Fz sensor

are 300N, and Mx sensor, My sensor and Mz sensor are 5Nm respectively. The maximum interference error of the six-axis force/moment sensor is less than 2.31%, and the maximum repeatability error rate and the maximum non-linearity error rate of the six-axis force sensor are less than 0.02% respectively.

The HSFMD is used to measure the grasping forces from the six-axis force/moment sensor and to display the values to LCD. It is composed of a DSP (digital signal processor), a memory, several amplifiers, a communication feature, power, several switches, and so on. The size of the manufactured control system is about 100mm×100mm.

3. Characteristics test of the spherical object grasping using SDFFMS

3.1 Characteristics test of normal people using SDFFMS

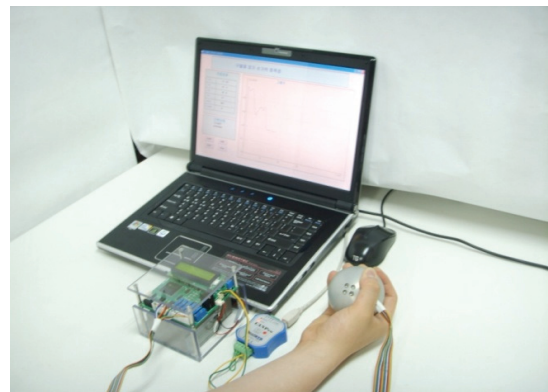
The spherical object grasping test could be carried out to judge the rehabilitation extent of a patient’s fingers in rehabilitative care. The rehabilitation extent could be judged by grasping a spherical object with the SDFFMS made in reference,⁷ thereby generating spherical object grasping force data from the characteristics test. In this paper, the characteristics test of the spherical object grasping was carried out using the SDFFMS, with forty male and forty female university participants.

Fig. 3 shows the experimental equipment for the characteristics test of the SDFFMS, and it is composed of the system and computer. When the patient grasps the spherical object, the finger grasping forces are measured from the six-axis force/moment sensor, and the forces are indicated on LCD and sent to the computer. The measuring value is acquired by measuring values three times.

Table 1 shows the results of finger grasping forces of the right and the left hands in characteristics test of the right-handed (the force of right hand is more strength that left hand) men and women using the SDFFMS. The average values of the finger forces (combined forces from equation (1)) for the right and the left hands of men were each 163N and 143N, and those of women were each 88N and 76N. As a result of characteristics test, the finger grasping forces for the right hands of both men and



(a) Left hand



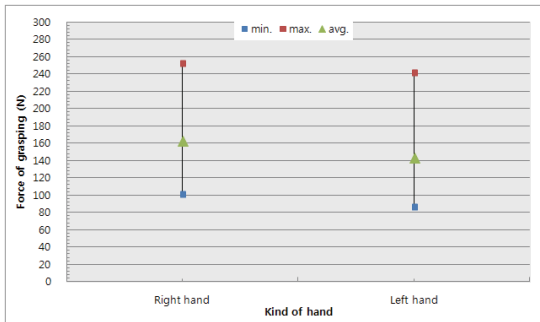
(b) Right hand

Fig. 3 Experimental equipment for characteristics test of the spherical object grasping using the SDFFMS

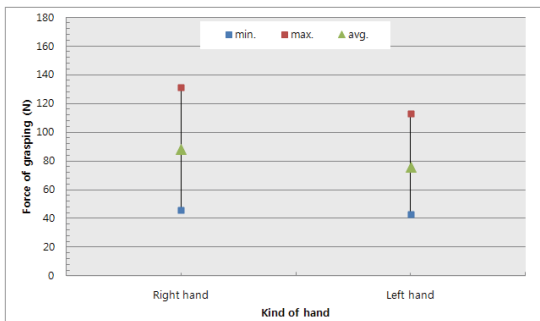
Table 1 Results of the finger grasping forces of right hands and left hands in characteristics test of the right-handed men and women using the SDFFMS

No.	Force of men (N)		Force of women (N)	
	Right hand	Left hand	Right hand	Left hand
Avg.	163	143	88	76
Max.	252	242	131	113
Min.	101	87	88	43

women are greater than those of the left hands. The gap between maximum value and minimum value is large because of grasping force of each person, lengths of fingers, and the method of grasping etc. Fig. 4 shows the graphs of Table 1, and it is so convenient that the results of patients with finger paralysis can be compared to them.



(a) Fingers of the right hands and the left hands of men (the right-handers)



(b) Fingers of the right hands and the left hands of women (the right-handers)

Fig. 4 Graphs of results of characteristics test using the SDFMS

3.2 Characteristics test of stroke patients and the judgment method of the rehabilitation extent

The spherical object grasping test was carried out to judge the rehabilitation extent of stroke patients' fingers in rehabilitative care. Fig. 5 shows photographs of the characteristics test of the spherical object grasping by stroke patients with finger paralysis using the SDFMS, and the tests were performed by four male and four female.

The first judgment method of the rehabilitation extent is to estimate the finger grasping forces of stroke patients by applying to the graphs made in the finger grasping forces of normal persons. Table 2 shows the results of the finger grasping forces of four men and four women stroke patients (the right-handers). Person A and B of four men stroke patients have normal right hands and abnormal left hands, and C and D are the reverse of A and B. And those of women are the same as men. In order to judge the rehabilitation extent of stroke patients'



(a) Left hand



(b) Right hand

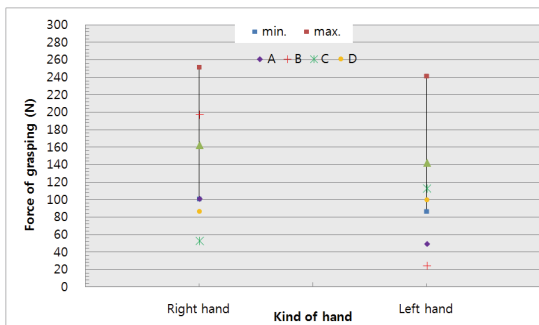
Fig. 5 Characteristics test of stroke patients with finger paralysis using the SDFMS

fingers in rehabilitative care, the finger grasping forces of eight stroke patients in the Table 2 apply to the graphs of Fig. 4(a) and (b). The Fig. 6(a) shows the graphs of finger grasping forces of four men stroke patients with fingers paralysis added to the graph of the grasping forces in the Fig. 4(a), and the Fig. 6(b) shows that of four women added to the graph the Fig. 4(b).

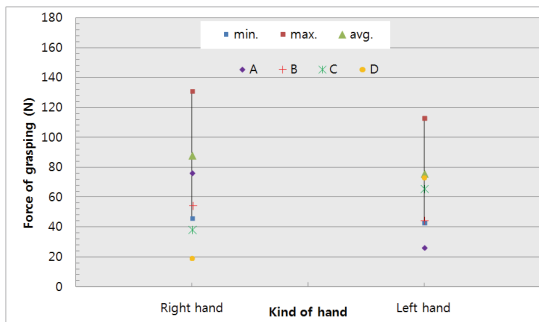
As shown in Fig. 6(a), the grasping force of the right hand of patient B was larger than that of the average force of normal persons, but that of the left hand with paralysis fingers was much less than that of minimum force of normal persons. That of the right hand of A was similar to that of the minimum force, but that of the left hand was much less than that of minimum force. So, it was roughly judged that the rehabilitation extents of the left hands of A and B were not almost recovered. And the rehabilitation extent of the right hand of D was almost recovered, but that of C was not recovered. As shown in

Table 2 The results of the finger grasping forces of four men and four women stroke patients (the right-hander)

No.	Grasping force of men (N)		No.	Grasping force of women (N)	
	Right hand	Left hand		Right hand	Left hand
A	101	50	A	75	26
B	198	25	B	54	44
C	53	113	C	38	65
D	87	100	D	19	72



(a) Men



(b) Women

Fig. 6 Graphs of grasping forces of patients with finger paralysis

Fig. 6(b), it was judged that the rehabilitation extent of the left hand of B was almost recovered, because those of the right and left hands were near the average force of normal persons. But the extent of the left hand of A was little recovered, because that of the right hand of A was larger than that of average forces and that of the left hand of A was similar to that of minimum force. And the right hands of C and D were not recovered. The results were in accordance with the diagnosis of a medical specialist in that field. The judgment method of the rehabilitation

extent is to compare the measured finger grasping forces of stroke patients' abnormal fingers with the grasping forces of normal people as shown in Fig. 6.

In order to judge the rehabilitation extent of the left-handed stroke patient (the force of left hand is more strength than right hand), the grasping force graph of left hand could be used the first graph, and that of right hand could be used the second graph in the (a) and (b) of the Fig. 4. It is shown that the finger grasping forces of Left-handers and the right-handers are surmised almost similarly.

The second judgment method of the rehabilitation extent is as follows; the finger grasping forces of abnormal hands are calculated from those of normal hands, and the measured finger grasping forces of abnormal hands are compared to the calculated forces. So, the rehabilitation extents of stroke patients' fingers could be more quantitatively showed. The calculated finger grasping forces of abnormal hands can be gotten the equations (2) and (3).

$$CL = La - (Ra - Rm) \times \frac{La}{Ra} \quad (2)$$

$$CR = Ra - (La - Lm) \times \frac{Ra}{La} \quad (3)$$

Where, CL is the calculated finger grasping force of abnormal left hand, CR is the calculated finger grasping force of abnormal right hand, La is the average finger grasping force of normal persons' left hand, Ra is the average finger grasping force of normal persons' right hand, Lm is the measured finger grasping force of left hand of stroke patient, Rm is the measured finger grasping force of right hand of stroke patient.

Table 3 and Table 4 show the calculated finger grasping forces of abnormal hands by using the equations (2) and (3), and the rehabilitation extents of male and female's stroke patients respectively. The rehabilitation extents of man A, B, C and D were about 47%, 86%, 56% and 19%, and The rehabilitation extents of women A, B, C and D were about 61%, 8%, 48% and 77% respectively. Therefore, it was judged that the D of men and the B of women were almost recovered. The difference between the first judgment method and the second is that one is to estimate roughly and the other quantitatively.

Table 3 Calculated finger grasping forces of abnormal hands and the rehabilitation extents of male stroke patients

No	Avg. force (N)		Grasping force (N)		Calculated force(N)		Extent of Reha. (%)	More strength hand
	Ra	La	Rm	Lm	CR	CL		
A	163	143	101	50	-	89	-44	Right-hander
B	163	143	198	25	-	174	-86	Right-hander
C	163	143	53	113	129	-	-59	Left-hander
D	163	143	87	100	114	-	-24	Left-hander

Table 4 Calculated finger grasping forces of abnormal hands and the rehabilitation extent of female stroke patients

No.	Avg. force (N)		Grasping force (N)		Calculated force(N)		Extent of Reha. (%)	More strength hand
	Ra	La	Rm	Lm	CR	CL		
A	88	76	75	26	-	65	-60	Right-hander
B	88	76	54	44	-	47	-6	Right-hander
C	88	76	38	65	75	-	-50	Left-hander
D	88	76	19	72	83	-	-77	Left-hander

4. Conclusions

In this paper, two judgment methods of the rehabilitation extent for stroke patients' fingers were presented using the SDFMS.⁷ The first judgment method of the rehabilitation extent is to estimate the finger grasping forces of stroke patients by applying to the graphs made in the finger grasping forces of normal persons. The second judgment method of the rehabilitation extent is to estimate the measured finger grasping forces of abnormal hands comparing to the calculated finger grasping forces of abnormal hands. It was confirmed that the rehabilitation extents of stroke patients from two judgment methods were similar to those of a medical specialist. It is thought that two judgment methods are used to judge the rehabilitation extent for stroke patients' fingers with the SDFMS.

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