DEVELOPMENT OF TRANSFER SYSTEM FOR THE HIGH SPINAL CORD INJURED PERSON

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Summary

We have developed the transfer system (named TS-1) for the severely handicapped person. In this transfer system two electric motors are used as lifting and traveling power sources, and electromagnetic powder clutch mechanism as lifting power transmission system. The transmitting torque through the electromagnetic powder clutch is proportinal to the quantity of current supplied to the electromagnetic powder. When this system starts to lift up and down the load, the quantity of current to the electromagnetic powder is controlled to be increased or decreased gradually. Consequently, using such clutch mechanism, the transfer system can lift up and down the patient very smoothly. Moreover, the torque for lifting is automatically balanced against the weight of the load. Therefore, when a helper lifts up and down the patient using this system, he can perform the task under the state of nongravitation, as it were.

We set up the transfer system at a patient's (level C5) house, and contrived the operation switches, hanger and slings for him to be able to use them for himself. In the result, he became to be able to transfer himself from bed to wheelchair and vice versa without help of others. In addition, he had been trying to put on and off his clothes for himself, and became to be able to put on and off the trousers and underpants alone using this transfer system and some self-help devices.

Introduction

There needs various technical aids for the severely handicapped persons to be able to live as independently as possible, and for the helpers to be lightened of their burdens. At the mention of the high spinal cord injured person, it is very difficult or impossible for them to transfer himself from bed to wheelchair and vice versa. And when they take a bath, helpers must assist them with considerable physical burdens. Impossibility of transfer action makes their rehabilitation very difficult. So, we took intrest in developing the transfer system. And, lately, we have developed new transfer system (named TS-1) for the high spinal cord injured person. We set up the transfer system at a high spinal cord injured person's house and contrived the suspending devices and switches to be handled by him as easily as possible.

Subject

We selected one subject (male) for this study. He is 32 years old, 172cm tall, and 52kg weight now. He was injured in the spinal cord at C5 level by diving when he was 17years old. Since then, his lower extremities have been quite paralyzed and he has been using

wheelchair in his everyday life. The functions of his shoulder muscles, biceps brachii, forearm abductor and wrist extensor are remaining to some extent. But the function of his triceps brachii has been quite paralyzed. Consequently, as he can never perform push-up action, he cannot transfer himself alone. He usually depends upon the help of his parents when he transfers between his bed and wheelchair and takes a bath. He is eager to live his life with the least assistance of others, but the impossibility of transfer action prevents him from being independent.

Development of transfer system TS-1

(a) Driving mechanism of TS-1

TS-1 that we developed can lift up and down, and move the patient laterally by the power of two electric motors(A.C.100v). The function of moving the patient laterally is realized by the electric trolley running over the rail on the ceilling. The driving mechanism of TS-1 is shown in Fig 1. The driving power source unit of TS-1 including electric motor for lifting, gear, electromagnetic powder clutch, winding drum and electromagnetic brake is set up outdoors. Therefore, when TS-1 is in operation, it makes little noise indoors.

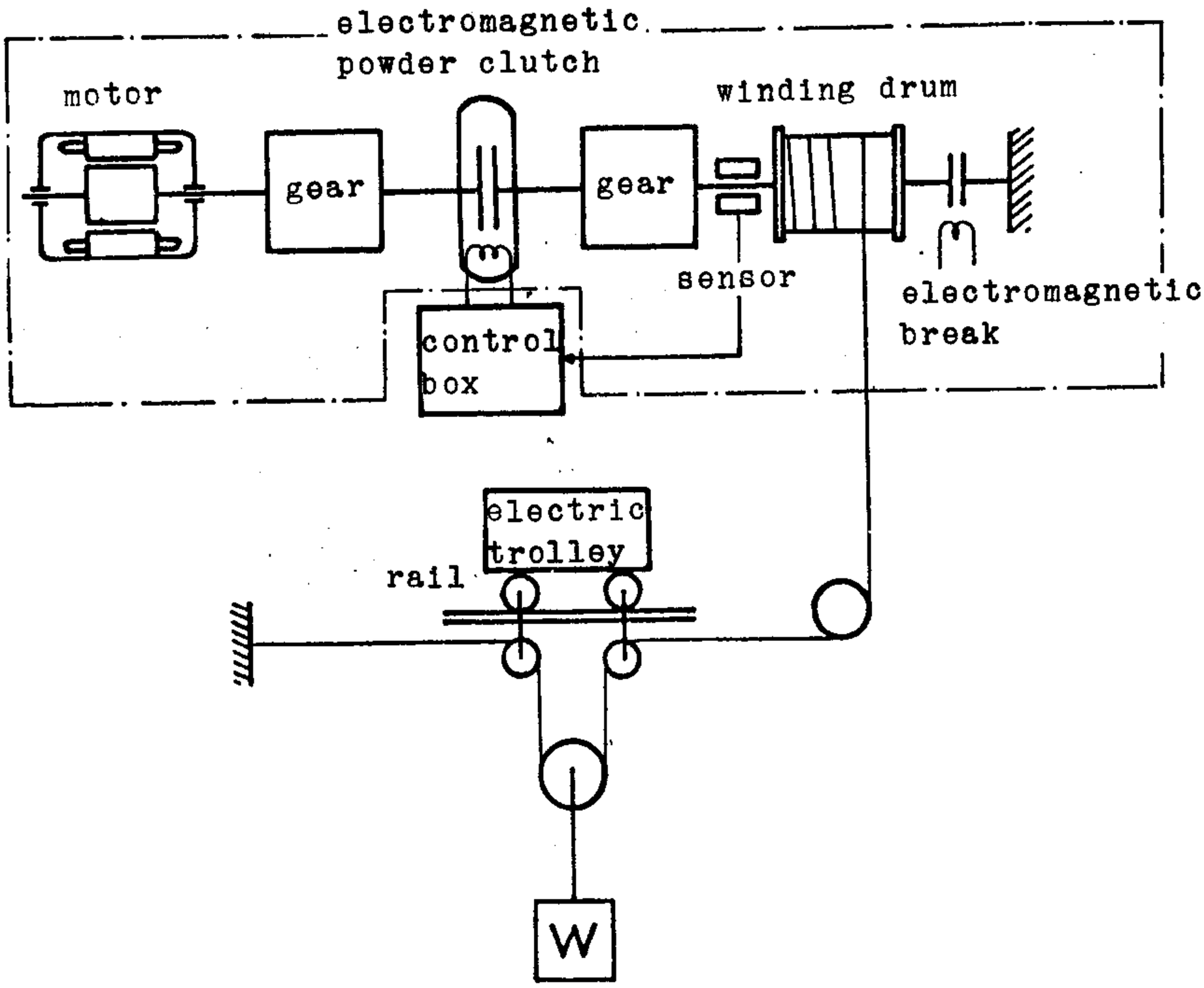


Fig 1. Driving mechanism of TS-1

The motor of electric trolley for moving the patient laterally is operated in on-off action. On the other hand, in lifting the patient up or down, the force balanced motion is realized by using a electromagnetic powder clutch as a torque converter. The principle of realizing the force balanced motion is as the following. In lifting up or down the patient, the torque generated by the electric motor is transmitted to the winding drum through the electromagnetic powder clutch. The electromagnetic powder clutch has the characteristic as shown in Fig 2. That is, the transmitting torque through the electromagnetic powder clutch depends not on the relative velocity of rotation between input and output, but on exciting current sent to the solenoid of the clutch. When TS-1 lifts up the load from the floor, exciting current

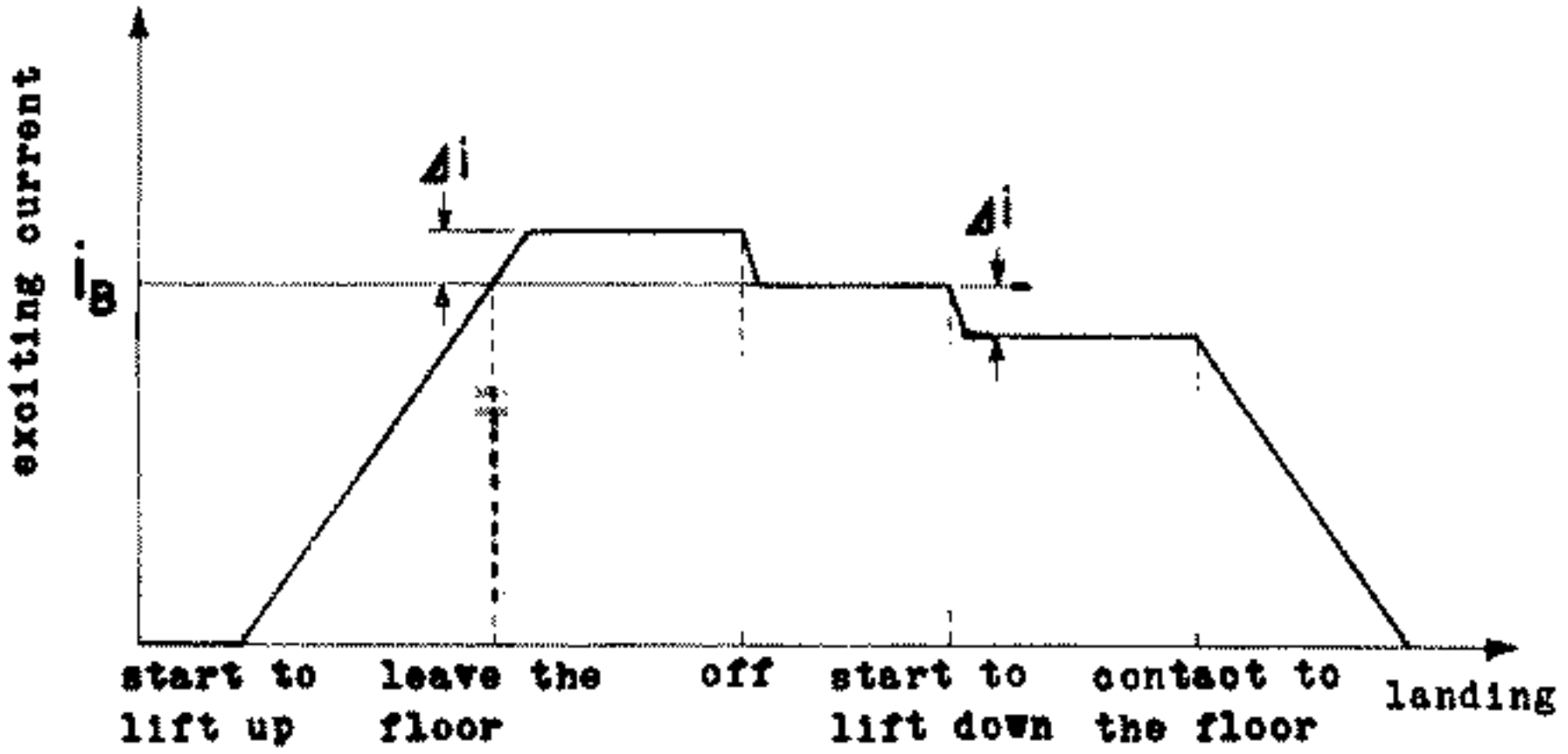


Fig 2. Relation between exciting current and situation in lifting action

sent to the solenoid is increased gradually, and the torque transmitted to the winding drum, that is, the force lifts up the load is increased slowly. Then, just the exciting current i_B of the moment when the load leaves the floor is stored. When the load is lifted up successively, the exciting current $i_B+\Delta i$ would be sent to the solenoid of the clutch. Then, if TS-1 is switched off to stop lifting the load, the quantity of exciting current is turned to be i_B, again. While the exciting current is maintained to be i_B, it balances the lifting force with the weight of the patient, and so, the helper could lift up or down the patient as if he were performing the task under the condition of weightlessness.

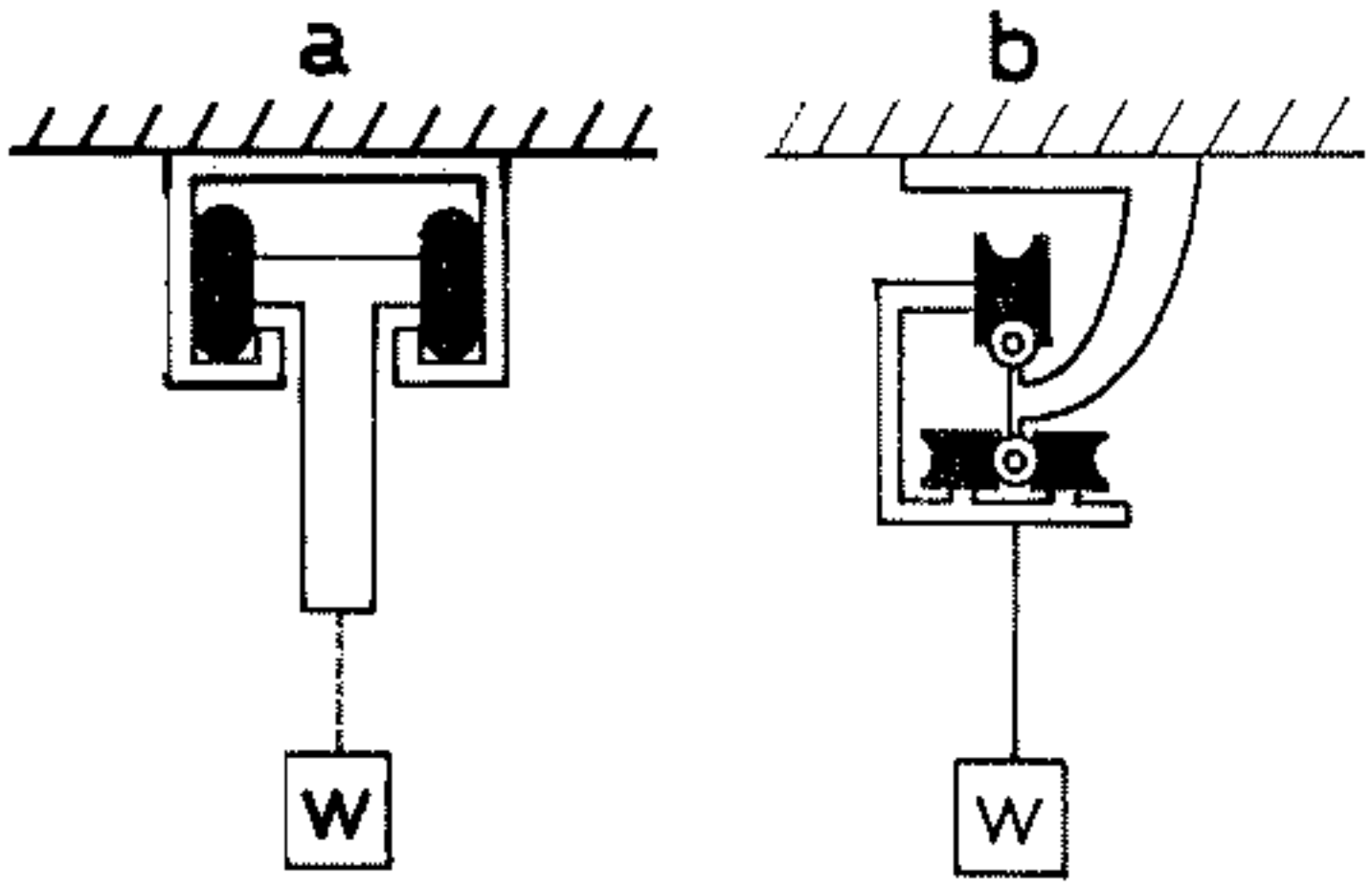
When TS-1 lifts down the load, the exciting current is turned to be $i_B-\Delta i$. Just when the load begins to come into contact with the floor, the exciting current sent to the solenoid is decreased gradually. Consequently, the lifting force given to the load is released slowly, and the load lands very softly.

By the way, the moment when the load leaves the floor or begins to come into contact with the floor is detected by observing the change of velocity of drum's rotation: the rotational sensor is mounted to the

winding drum, and just when the load leaves the floor or begins to come into contact with the floor, the velocity of rotation of winding drum changes to be regular from to be irregular or changes to be irregular from to be regular respectively.

(b) Rail for TS-1

We designed the new type of rail for TS-1. It is made of two stainless steel pipes, and the structure is as shown in Fig 3-b. Having been such structure, the weight of rail for TS-1 turned out to be one third of that for conventional type lifters shown in Fig 3-a. And more significantly, it seems to be very easy to inspect troubles and to repair them.

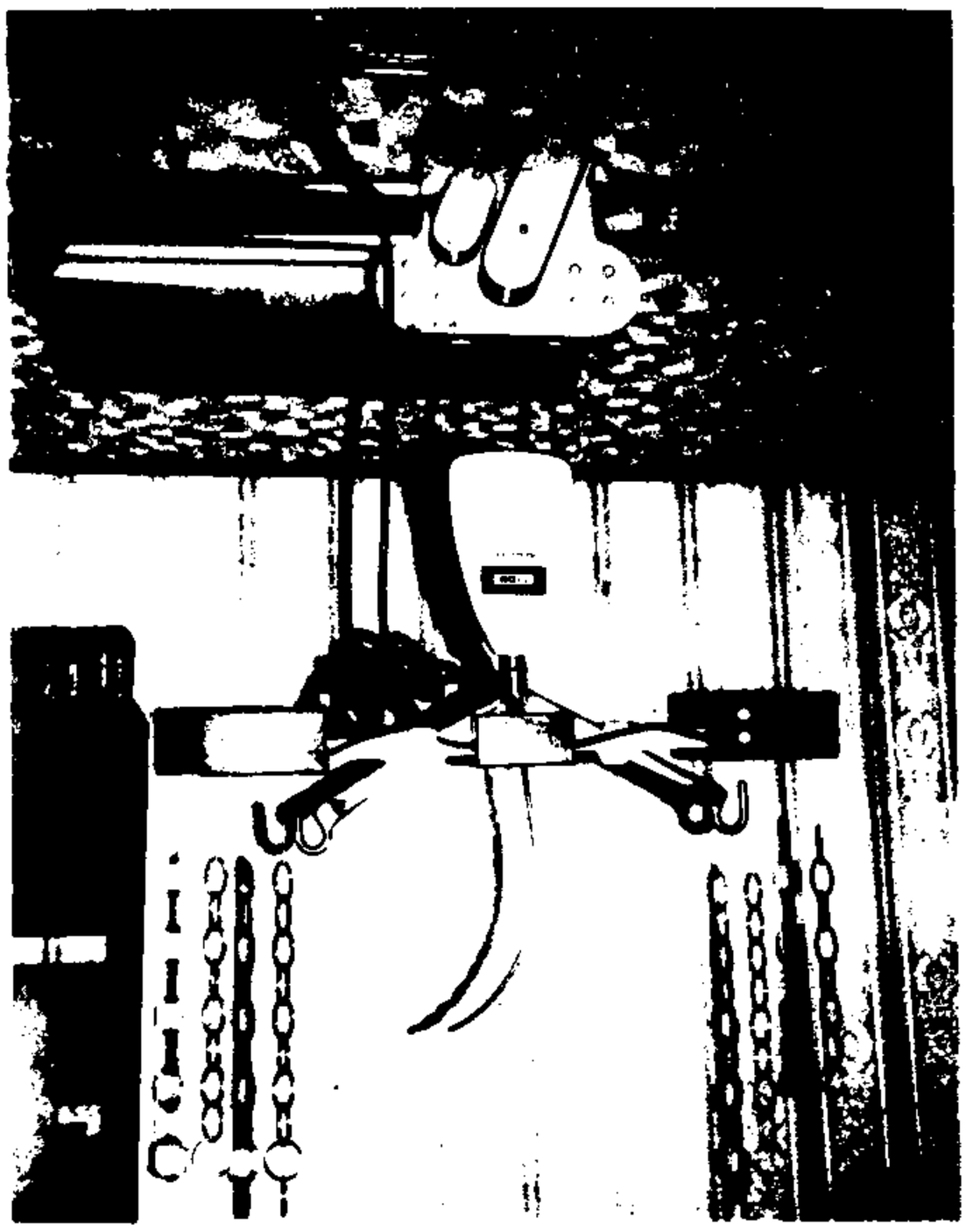


conventional type for TS-1

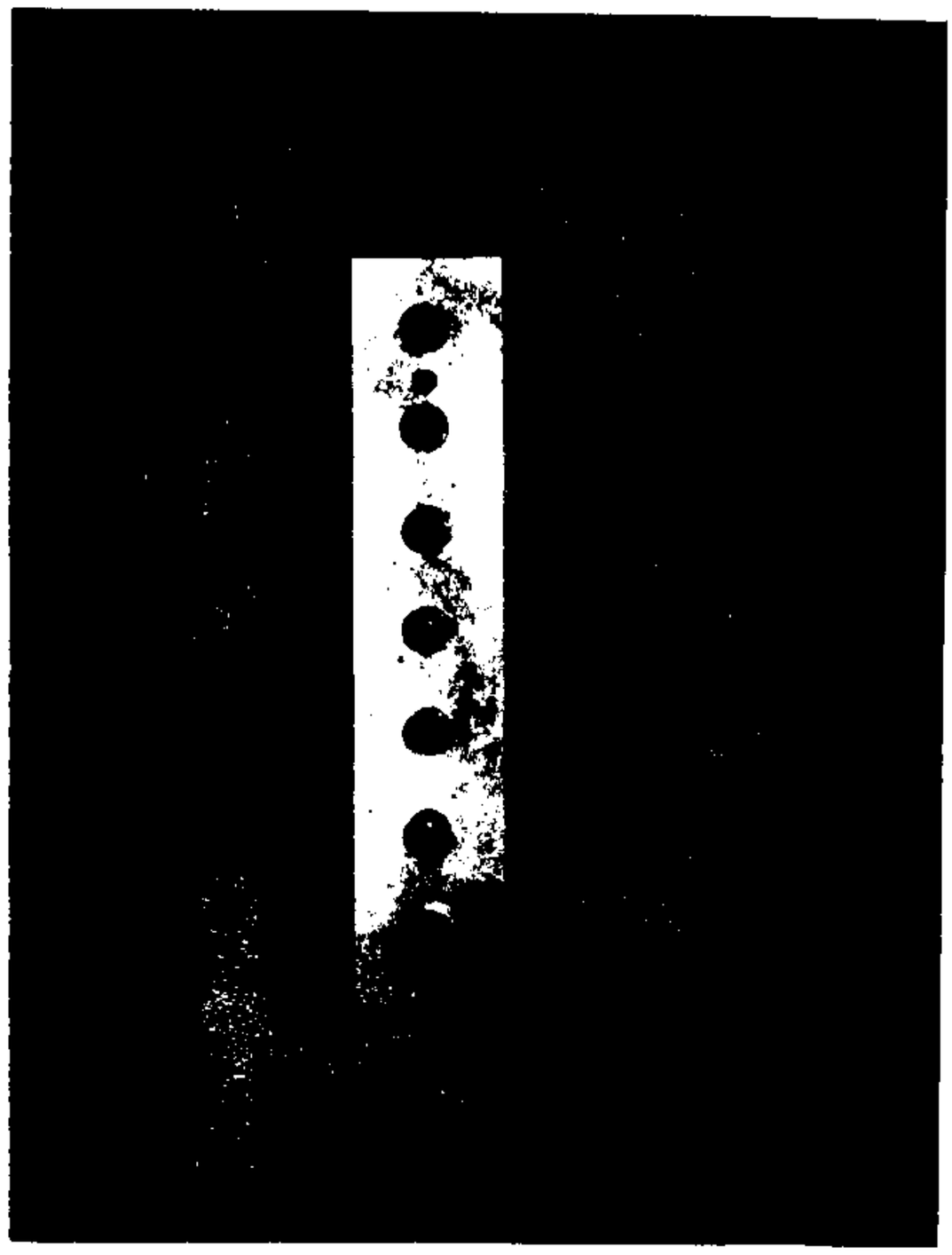
Fig 3. Rail for transfer system

(c) Operation switches

We provided two systems of operation switches for TS-1. One is the arrangement of pull switches and pressure switch actuated by puff and sip, which are mounted to the hanger of TS-1 as shown in Fig 4-a, and the other is pendant type switch as shown in Fig 4-b. The former would be handled by the patient on TS-1, and the latter mainly on the bed. When the patient is on TS-1 and operates the switches, he could not operate them quickly by using only residual functions of upper limbs. Therefore, we provided the pressure switch actuated by puff and sip to control the electric trolley. Loops are attached to each switch in order that the patient can handle it for himself with ease.



a. Switches mounted to the hanger



b. Pendant type switch

Fig 4. Operation switches for TS-1

(d) Consideration for safety

TS-1 is worked by A.C.100v electric power, and is used not only in bed room but also in bath room. Therefore, we adopted prudential means to prevent the patient from being struck by electricity:

a) ensured perfect earth of electric current,
b) made the electrical devices dampproof,
c) equipped the sensitive electric leak breaker that is actuated by leakage of 5mA current during 0.1sec,
d) used the Ni-Cd dry cell battery (D.C.6v) for the power source of operation systems that the patient or helpers handles.

By the way, in TS-1, the winding drum's shaft is connected to the electromagnetic break which acts when the electric power is cut off. In consequent, if it happens a power failure by accident while the patient uses TS-1 alone, the break acts to prevent him from swiftly falling, and adjusting the break force, the patient falls very softly.

Slings for TS-1

In the conventional type lifters, sheets (one-piece type or two-piece type) have been using to support the patients. However, using sheets, it would be impossible for the severely handicapped persons to put on them without assistance of others.

Therefore, we chose two belt-type slings for TS-1, so as to be possible for the subject to put on them for himself. They were made of seat belt for automobile and urethane foam. He would put them on his trunk and thighs separately for himself. Optimum length of each sling was determined so that he would be suspended in a sitting

position on the wheelchair. Several loops were stitched to each sling in order that he could handle it for himself with ease.

Result

(a) Performance tests

Before being set up at the subject's house, TS-1 was tesed about its characteristics of action when it performed the tasks with 63 kg loaded. The velocity of lifting the load up and down and moving it along the rail and the acceleration of lifting it up and down were determined. For comparison, another two types of lifters which are commercially available were also tested about the same items as above mentioned.

The result are shown in Table 1 and Fig 5. "K" is originally for industrial use, and so it gives much shock to the load when it starts to move or stops. However, in our country some patients are using it because of its cheapness. Judging from Table 1 and Fig 5, it is said that the features of adopting the torque control system in lifting function of TS-1 are remarkably shown in the results of acceleration test. Comparing TS-1 with "Y", it is evident that TS-1 acts much mor softly for its movement velocity.

Table 1. Velocity of action (m/min)

	up	down	lateral
TS-1	4.9	5.2	7.4
K	8.1	8.7	21.8
Y	1.9	2.1	10.8

with 63 kg loaded

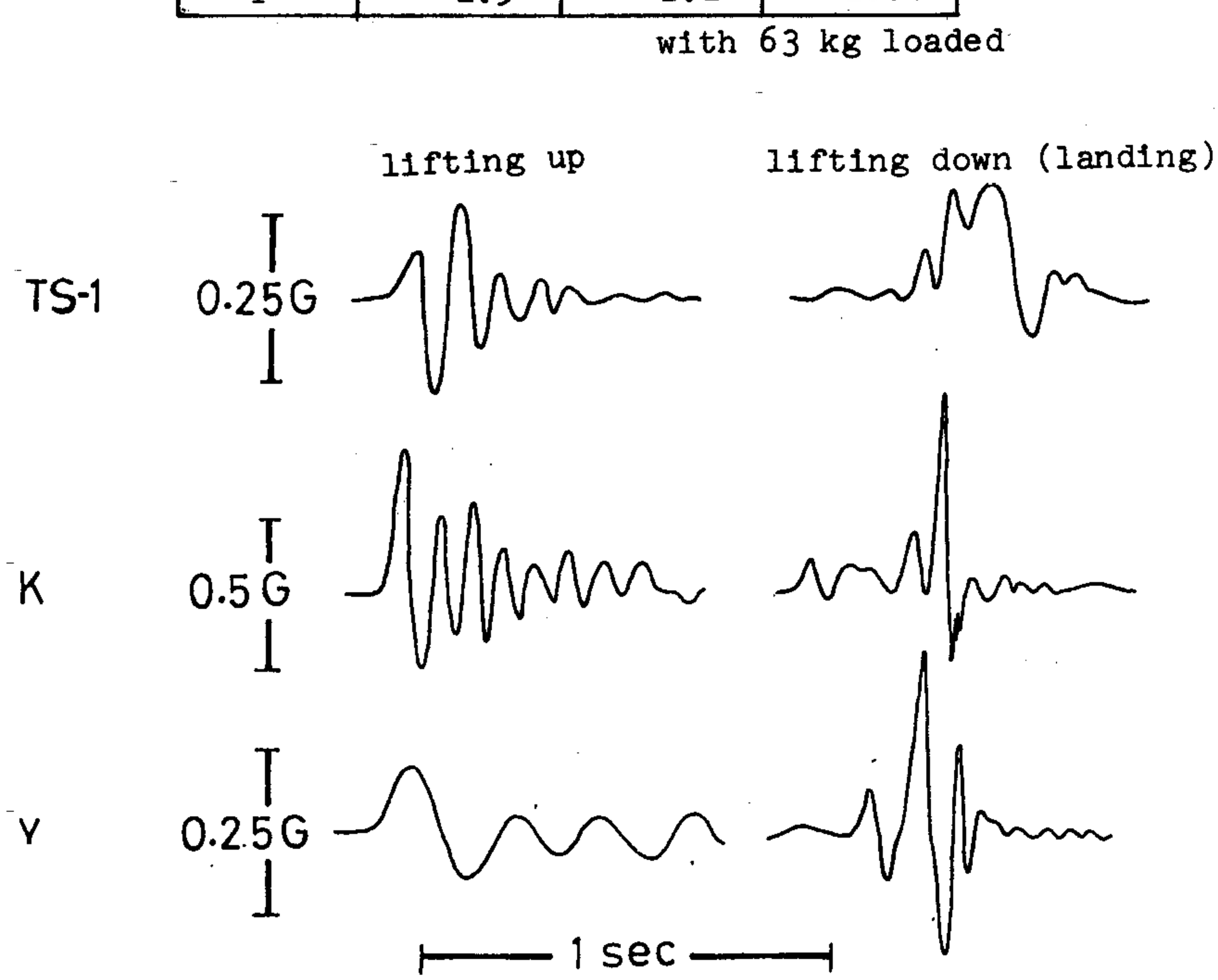


Fig 5. Acceleration in lifting up and down

(b) Availability in actual life

TS-1 has been set up at the subject's house to be evaluated about its availability in his actual life. At the same time, his room and bathroom has been adapted to arrange his bed and bathtub in the straight line of rail of TS-1.

In the result, the extent of activities that he can perform without any assistance of others has been remarkably expanded by using TS-1.

He has become to be able to transfer from his bed to wheelchair and vice_versa perfectly for himself using TS-1: as we contrived the operation switches, hanger and belt-type slings so as to be handled by him as easily as possible, he was able to put the belt-type slings on his trunk and thighs and to operate the switches by his own efforts. Finally, he has become to be able transfer himself, including putting on and off the slings, in about 7 min. from bed to wheelchair, and in about 5.3 min. from wheelchair to bed. Fig 6 represents his transfering between his bed and wheelchair.

a. Front view b. Side view

Fig 6. Transfering between bed and wheelchair

Furthermore, it is worthy of special mention that he has become to be able not only to transfer, but also to put on and off his clothes especially trousers and underpants applying the functions of TS-1. He could put off his trousers and underpants on his wheelchair alone using TS-1. Elastic strings with hooks at their tip are attached to both armrests of his wheelchair, and loops are sewed on both sides of his trousers and underpants. Then, his trousers or underpants can be connected to the elastic strings by the hooks and the loops. If he lifts himself up by TS-1 suspending only his trunk, his trousers or underpants will be slipped down by the aid of the elastic strings.

By the way, he could put on his trousers and underpants on his bed

also using TS-1 ingeniously. He uses TS-1 to lift his leg one by one, and then, he can let his leg through his trousers or underpants.

With regard to bathing, it was not premised that he would be able to take a bath for himself using TS-1, but was aimed that TS-1 would save much labor of helpers. In the result, helpers (parents) have be remarkably lightened of their physical burden when they helped him to take a bath.

Conclusion

We selected one high spinal cord injured person (level; C5) as a subject, and pursued our study of developing the transfer system including satisfying his personal needs for devices and contriving operation systems and slings to be adapted to the residual functions of his upper extremities.

The fact that he has become to be able to transfer himself between his bed and wheelchair without any assistance of others encouraged him to try to put on and off his clothes for himself. And ultimately, he has become to be able to put on and off his trousers and underpants utilizing the functions of TS-1 and other devices we contrived.

These results we have achieved would be applicable to the other severely handicapped persons.

Acknowledgement

We would like to express our thanks to Mr. M. I. for his earnest cooperation to our study.