Monitoring rehabilitation training for hemiplegic patients by using a tri-axial accelerometer

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***Abstract*-In rehabilitation training for hemiplegic patients, bed-to-wheelchair transfer is most important and allows a patient's early independence. We developed a monitoring system for transfer training that is quantitative and uses accelerometry. Five hemiplegic patients participated in this study. Two tri-axial accelerometers were attached to the subjects, at the head and waist. Subjects were trained in moving from a sitting position to standing, then turning through about 90 degrees, and then sitting on the bed. The acceleration signals at the two sites were recorded via a multi-telemeter system, converted to a digital signal, and stored in a computer. Data were analysed by LabView and displayed on the computer screen as real time motion. The original signal was displayed with a superimposed image obtained from a CCD camera. The system can be operated by one staff member, and the patients did not feel restricted. We were able to evaluate the time course of the signals, and phase-plane locus of the vertical, lateral and horizontal directions of the signals. The transfer of hemiplegic patients occurred in two motions: a standing-up motion, and a sitting-down motion. Accordingly, we observed twin peaks in the plot of the original signal. In contrast, healthy volunteers moved smoothly and twin peaks were not present. This method might be effective in evaluating whether patients can transfer. The system could be useful for supporting rehabilitation training in transfer motion.**

***Key words*- Evaluation, rehabilitation training, transfer motion, accelerometry, hemiplegic patient**

I. INTRODUCTION

Early rehabilitation training is important for hemiplegic patients to achieve independent motion at an early stage. Therefore, we should evaluate the training in real time and then immediately reflect this evaluation in the training.

Transfer from bed to wheelchair is the most important rehabilitation training for hemiplegic patients and allows a patient's early independence [1]. We developed a quantitative monitoring device for transfer training using accelerometry. We evaluated the utility of the device in supporting therapists in Activities of Daily Living training.

II. METHODOLOGY

A. System configuration

Assembly of the system is shown in Fig. 1. This system comprised two tri-axial accelerometers, the telemetry system, and the data analysis system. The tri-axial accelerometers were connected to the transmitter of the telemetry system via DC amplifiers. The data analysis system comprised a data receiver, and a personal computer for data analysis. Six acceleration signals were collected during the transfer and sent to the transmitter via the DC amplifiers. The transmitted signals were received by a multi-telemeter system (Nihon Koden Co. Ltd, Japan) and converted to digital signals with a sampling rate of 256 Hz, then transferred to a personal computer for analysis by LabView (AT-MIO-16E-10, National Instruments, USA).

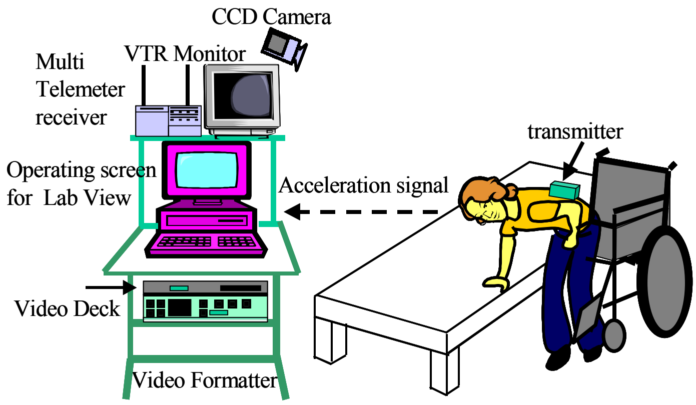

Fig. 1. Construction of the system

This system is able to display a patient's real-time acceleration signal on the screen of a personal computer. We used two methods of analysis. One used the original acceleration signal, and the other used the phase-plane locus of vertical, lateral, and horizontal directions of the signal. This system can be used for real-time evaluation of a patient's motion.

The system can produce an original acceleration signal together with a superimposed picture (obtained with a CCD camera) on the monitor screen. We were able to observe images of the patients as well as the acceleration signals in real time during transfer.

B. Subjects

The subject profiles are shown in Table 1. Patients were only selected if verbal communication was possible; we excluded patients who had severe disturbance of consciousness, severe dementia, or disturbance of high cortical function. In addition, six healthy volunteers participated in this study.

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TABLE 1 List of Subjects

Hemiplegic patients	five patients (three men, two women)
Age in years (mean ± SD)	62.2 ± 22
Right hemiplegia	two patients
Left hemiplegia	three patients
Level of transfer ability:	
independence	three patients
supervision	one patient
assistance	one patient
Control volunteers	six subjects (three men, three women)
Age in years (mean ± SD)	24.5 ± 1

C. Data analysis

Original acceleration signals obtained from tri-axial accelerometers were plotted in chronological order, and we observed each movement direction in the achievement of transfer. In addition, we analysed a characteristic of motion in the phase-plane locus of vertical, lateral and horizontal directions of the signal [2].

D. Method of measurement

Two tri-axial accelerometers were attached to the subjects, at the head and waist (Fig. 2).

We considered that the head acceleration signal contained motion information for the upper trunk and part of the neck, and the waist acceleration signal contained information for the lower trunk and legs. The measurement task was to move from sitting in the wheelchair (41.5 cm) to standing, and then to sitting down on the edge of the bed (41.5 cm). We asked subjects to use their preferred method of transfer that they used each day. We did not train them in a new transfer method. The transfer motion was recorded from beginning to end on videotape, using the CCD camera.

The ethics committee of Fujimoto Hospital approved this study, and written informed consent was obtained from subjects and their families before the experiment.

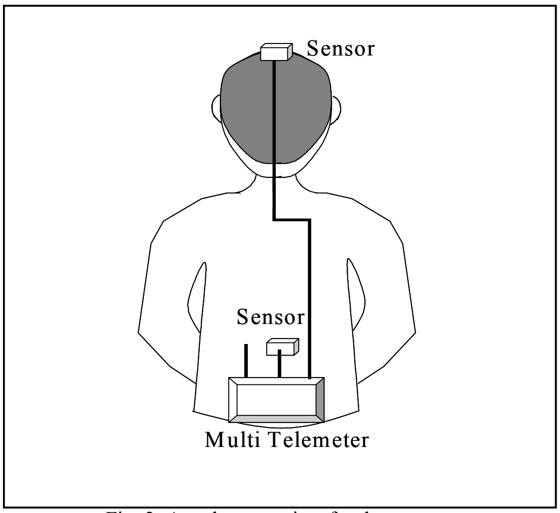

Fig. 2. Attachment points for the sensors

III. RESULTS AND DISCUSSION

1. The device could be operated by one staff member, and the patients did not feel restricted. It was suggested that we could apply this system to training of patients in how to transfer clinical rehabilitation.

2. In examination of original and chronological data, characteristic motions were observed in hemiplegic patients. Fig. 3a shows data obtained from a healthy subject (26-year-old man) who was asked to mimic the pattern of left hemiplegia. Data from a hemiplegic patient (45-year-old man, left hemiplegia) who can transfer independently are shown in Fig. 3b. For the healthy volunteer, the acceleration signal in the vertical direction was high compared with that of the hemiplegic patient. In general, preparation of posture is necessary for a stand-up motion. Flexions of trunk and neck are observed, and then the trunk moves forward with a change in the center of gravity.

However, for hemiplegic patients, only the trunk flexion was observed. When the trunk moved forward with the change in center of gravity, the neck extended, so the patient was looking at the ceiling. Accordingly, the acceleration signal in the vertical direction was lower.

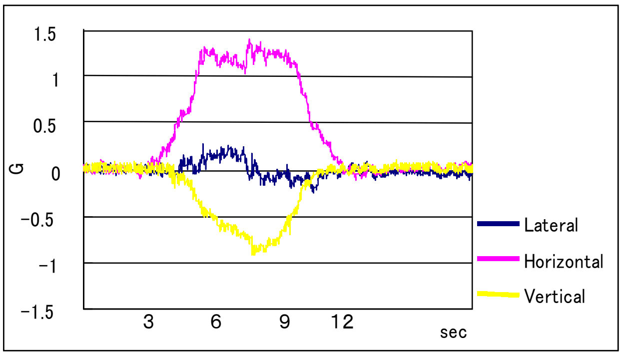

Fig. 3a. A typical signal for a healthy volunteer

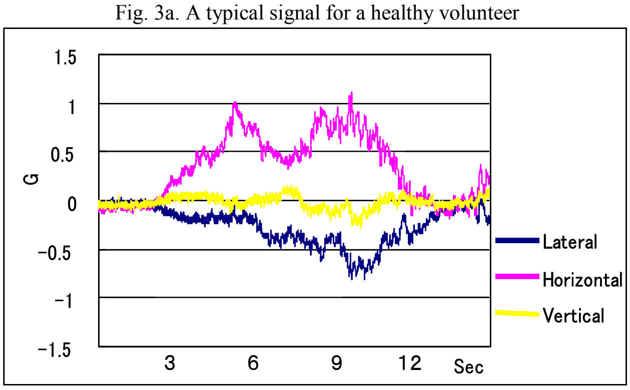

Fig. 3b. A typical signal for a hemiplegic patient

In addition, we observed twin peaks in the signal for the horizontal direction in the motion of hemiplegic patients. This clearly showed that hemiplegic patients make two motions: standing up, and sitting down. We confirmed that hemiplegic patients transfer in two motions in all cases. However, healthy volunteers moved smoothly, producing a single peak.

3. In evaluating the phase-plane locus of three directions of signals, we confirmed that the characteristics of the transfer motion occurred in the vertical and horizontal directions.

For the healthy volunteers, the standing-up motion was synchronized with trunk and neck flexion, and similarly for the sitting-down motion. Accordingly, the phase-plane locus traced a semicircular form (Fig. 4a). However, for hemiplegic patients, the vertical direction of the acceleration signal was low compared with that of healthy volunteers. Accordingly, the phase-plane locus traced a path parallel to the horizontal axis (Fig. 4b).

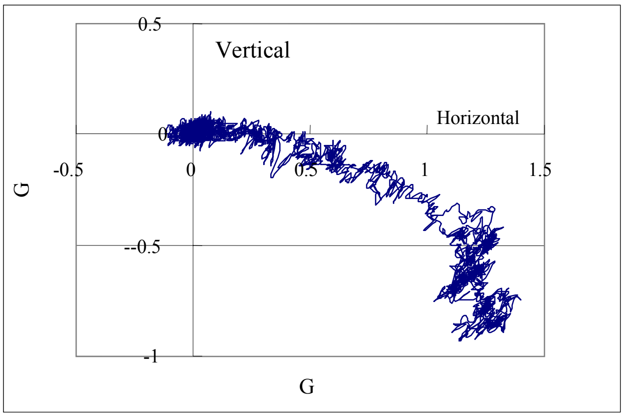

Fig. 4a. A phase-plane locus for a healthy volunteer

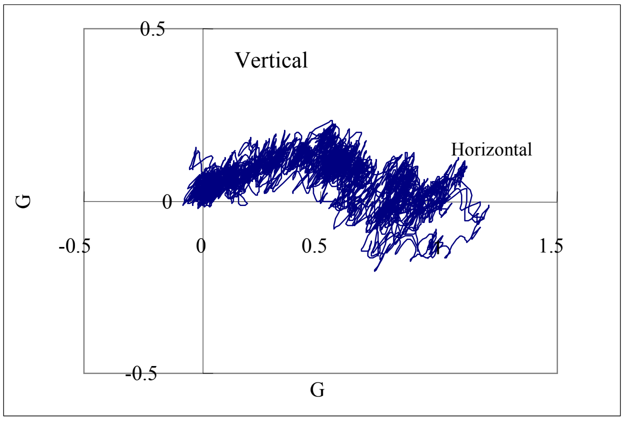

Fig. 4b. A phase-plane locus for a hemiplegic patient

This system will be useful for training during clinical rehabilitation, because it can be used to evaluate each patient's characteristic motion in real time. The system can provide necessary information for therapists in rehabilitation training.

V. CONCLUSIONS

1. This system will be useful for training during clinical rehabilitation, because it allows visual confirmation of the transfer motion, and quantitative evaluation for achievement of motion.
2. A hemiplegic patient's transfer occurs in two motions: standing up and sitting down. Thus, twin peaks appeared in the plot of the original signal.
3. The system can be operated by one staff member. Accordingly, it can be used for real-time evaluation for training during clinical rehabilitation.

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