beginning of standing on flooring and linoleum. Moreover, the posture angle in the lateral direction suggested that the patient could move the center of gravity to the affected site with the aid of the AFO.

Conversely, the patients used the large counter-reaction at the beginning of standing on carpet because of sinking. This large counter-reaction requires high control skills like the normal subject, since it might become an over-impelling force. In this situation, the patient could not maintain the standing position, and fell readily. During walking, part of the impelling force is obtained through an anteverted posture. The patients kept the anteverted posture to compensate for the impelling force of their lower limbs. In the lateral direction, they did not inclined during standing and walking. In other words, the patient stood and walked on carpet while avoiding putting their weight mainly on the unaffected side, since it was difficult to control body motion with the affected site.

Therefore, it was considered that a soft floor like carpet was difficult to provide sufficient reaction force to control the basic functions of an AFO. Nevertheless, carpet is one of the most popular floor materials. Consequently, we need to train hemiplegic patients to walk using several different floor conditions.

V. Conclusion

In this study, we evaluated the influence of three different floor materials (flooring, linoleum, and carpet) on standing and walking in hemiplegic patients. Our major finding was that the pattern of the posture angle differed on carpet from those on flooring and linoleum. Although this experiment examined only six hemiplegic patients, it was thought that body motion is influenced by the hardness of the floor material.

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A mobile-phone based telecare system for the elderly

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Abstract— **This study examined the use of telecommunications for home health care and described an alternative telemedicine framework. The framework aims to transmit small but sufficient amounts of data for daily monitoring of residential subjects' basic health status. We tested the remote monitoring of heart rate and respiration. The system was tested in real home-visit rehabilitation environments and was found to be useful both for the therapist and the patients in planning and evaluating daily rehabilitation training.**

Keywords—**telecare, rehabilitation, vital sign, mobile phone**

I. INTRODUCTION

The Long-Term Care Insurance System aims to help the elderly remain self-sufficient by providing benefits for home health care services. Unlike hospital care, home care services are difficult to plan, manage, and evaluate, particularly in homes that are located far from the hospital. Telecommunication technology support is expected to redress this distance problem.

For home health care, research has focused on developing systems that can be used by therapists to remotely monitor individual patients. Thus, the telecommunication performance requirements are relatively low. Additionally, because such a system should be maintained daily, cost is strongly limiting. For considering above limitation, we developed a simple telecare system.

II. METHODOLOGY

2.1 System configuration

The system consists of a sensory system for the home and a viewer system for the therapist. A TCP/IP network using various physical communication infrastructures connects the sub-systems.

The home-side system, shown in Fig. 1, consists of an air-filled mat, a sensory and analysis unit, and a bridge unit that handles connections. When a subject lies on the mat, the mat senses pressure from the subject's respiration or heartbeat. Heartbeat or respiration disturbances have robust frequency characteristics, with a relatively low frequency in relation to environmental noise. Thus, by applying an appropriate filter, readings can be extracted to estimate respiratory and heart rates. Pulsemeters are widely used to determine heart rate. However, these devices must attach the subjects and then constrain subjects and decrease their quality of life. Computer vision and image processing have been proposed for determining respiratory rate, but this system would require complex imaging hardware. In contrast, our method can estimate heart and respiration rates simultaneously, without any constraints on the subject, using relatively simple hardware.

The analysis unit (Bio-Sensor Node BN-6, Yokogawa Electric Corp.) continuously monitors pressure perturbations with a pressure sensor and estimates rates for predefined timeframes. Estimates are stored in a built-in web server system in HTML format, accessible via an integrated Ethernet interface. An embedded microserver unit (OpenBlockSS, Plat Home Inc.) serves as the bridge unit. Since the unit is integrated in a fanless microcomputer module, it conforms to the silence requirement described above.

The choice of networking infrastructure for telemetry is very important. In conceptual telemedicine, high-quality, wired connections like xDSL or FTTH are sometimes assumed for the infrastructure. However, large gaps in the high-quality connection infrastructure still exist, making these connections unreliable for practical use. Additionally, even if the infrastructure were available, the installation responsibilities and maintenance costs would become issues. Thus, we decided to employ a wireless network using mobile phone terminals for both ends of the connection. A wireless network also resolves the issue of cost and responsibility, since hospitals would not have to provide phone terminals. In our system, a mobile phone modem (MobileDP 2496P, NTT DoCoMo Corp.) connects the bridge unit and a mobile phone.

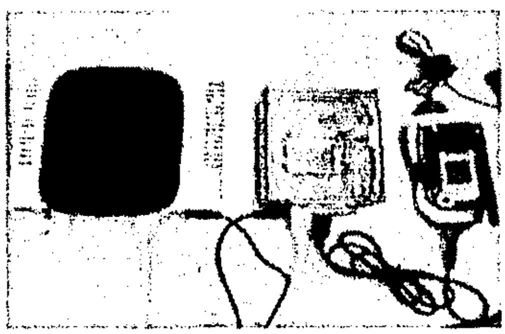

Figure 1 System configuration

2.2 Therapist-side viewer system

Therapists would access the home-side sensor node to browse a subject's status and could quickly check various patients. To track or record long-term transitions in health status, the system would have to store and arrange acquired information. In addition, if signs of emergency arise, the hospital side would have to contact the home side immediately.

Since therapists do not necessarily have expert computer knowledge, the viewer system should have a simple interface that does not require special knowledge for setup, browsing, or reporting. We therefore developed a viewer system using a personal digital assistant (PDA) and a mobile telephone. Today's PDAs have web access via popular web-browser interfaces, as well as simple text-editor functions suitable for making reports. An infrared modem links the PDA and the mobile phone.

2.3 Connection

The connection between the sensor and the viewer system should be carefully balanced between performance and cost. Our system requires information on estimated heart rate and respiratory rate at several points after exercise. Such data use a few kilobytes of space at most, even when formatted in HTML text. If formatted as HTML, on-request rather than permanent connections should be designed.

2.4 Security and privacy

To ensure the subject's privacy, protection of measured data is very important when connecting the sensor and viewer terminals through a public communication infrastructure such as the Internet. Thus, privileged access or encryption should protect the data. Our system limits access to the phone number for incoming calls to the bridge unit. Additionally, password authentication is requested when connecting.

2.5 Experimental Set-up

We operated the system in real patients' homes to evaluate its potential. We conducted the testing in Miyazaki Prefecture, Japan. A therapist from Fujimoto Hayasuzu Hospital and two residential patients joined in the experiment. Prior to the experiment, the hospital's ethics council ensured that the patients and their families had given both oral and written informed consent.

2.5.1 Subjects

Case 1: The patient was an 83-year old male who had been hospitalized for cerebral infarction with intercurrent deglutition pneumonia. After recovery, the patient and his family requested home-visit care. The patient was bedridden and, other than meals, needed complete support in the activities of daily living. In terms of care insurance, the patient was at Level 4. Rehabilitation training by physical therapists included joint flexion, muscle rebuilding, mental support, platform-to-wheelchair assistance, and other basic activities. The patient lived in an intermountain area 28 km from the hospital. Only mobile phone infrastructure was available for wireless communication.

Case 2: The patient was a 54-year old female diagnosed with muscular dystrophy. Her mobility was impaired and she could move only on her hands and knees. The patient slept on a futon. In addition to assistance with eating and toileting, the subject required partial help with other activities of daily living. Rehabilitation training by the therapist included respiration aids, joint flexibility training, and muscular exercises. The subject's home was located at the center of the city, 3 km from the hospital. Both mobile phone and personal handy-phone infrastructures were available.

2.5.2 Installation

The system was placed in a briefcase for easy installation. Prior to the experiments, the therapist was given brief instructions on system installation and use. After the training, the therapist could install the system in five minutes.

2.5.3 Measurements

The therapist used the PDA system to measure heart and respiratory rates under the following three conditions:

1. At the hospital, 30-60 minutes before training,
2. At the patient's home, at the beginning and end of the training,
3. At an outdoor location, remote from both the home and hospital, 30-60 minutes after training.

III RESULTS

Figure 2 shows the locations of the hospital, patients, and outdoor setting. Each operation took approximately 2 minutes, including about 40 seconds for HTTP data transmission. Although radio wave malfunctions caused several lost connections, the system recovered easily by reloading via the web browser. The therapist used each measurement to check the patient's stability. Results were stored in a text document on the PDA to log transitions in the patient's status. Figure 3 shows the measurement results. In each case, although heart and respiratory rates increased immediately after training, the increased rates were considered safe and the subject recovered in 30 minutes

IV DISCUSSION

In both cases examined above, the system successfully obtained data on patient status. Because we simplified the system structure so that the therapist needed only to plug in to start or stop the system, the time and cost for installation and maintenance were appropriate for our needs. Patients also approved of the system's compact, silent, and non-constraining nature. Patients especially valued the non-constraint. Unlike systems that require patients or their caregivers to set up complicated devices, our system merely had patients rest on their bed or futon.

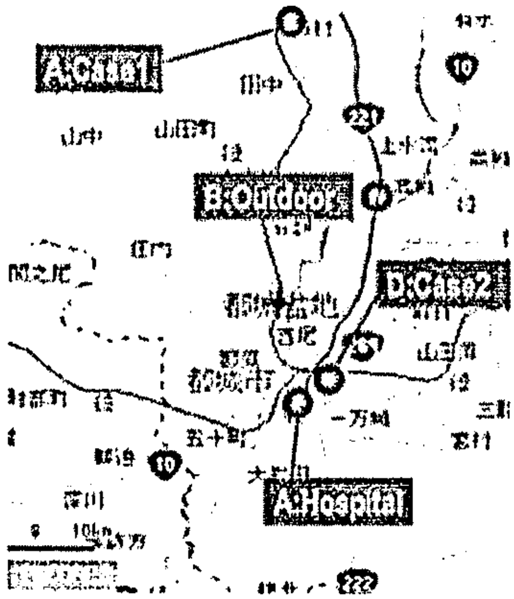

Figure 2 Locations of hospital and patients' home. Red circle shows the measurement points

We used a personal digital cellular (PDC) mobile telephone for data transmission. The phone requires a relatively low bandwidth (9600 bits/sec), and since we had limited the information sent to less than 50 kilobytes, transmission took a maximum of one minute to download. Recently, bandwidth for mobile phones has been improving. For example, wide-band code division multiple access (W-CDMA) has 384 kilobits/sec of bandwidth. Thus, it is possible to provide faster access. By providing data via web interfaces, the operations for browsing and editing results were easily understood by our user. With each measurement, the therapist could confirm that the patients had not suffered overloading shock from the exercises. Also, the logged data showed that patient status safely transitioned back to normal following exercise. The exercise training loads for both patients proved appropriate. While it is difficult to evaluate post-exercise transitions by interviews, our system can provide quantitative information for evaluation.

The quantitative data can be used not only for training evaluation but also for preventive medicine and quality control of home-visit rehabilitation services through long-term observations. Our test applications of home-visit rehabilitation suggest the efficiency of low-bandwidth, which can provide an ubiquitous framework for home health care use.

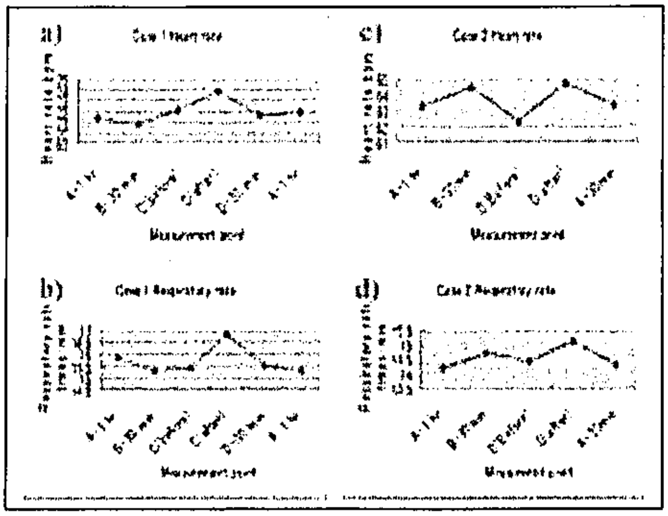

Figure 3 Results of heart and respiratory rates

V. FUTURE RESEARCH

In home rehabilitation, blood-pressure measurements are important in understanding patients' post-exercise status. For home health care not limited to rehabilitation, measurements of other physiological parameters can also be introduced. For example, to understand a patient's level of activity, a patient pedometer could be developed. Oxygen consumption is also useful in comprehending a patient's vitality.

VI CONCLUSIONS

This study examined the use of telecommunications for home health care and described an alternative telemedicine framework. The framework aims to transmit small but sufficient amounts of data for daily monitoring of residential subjects' basic health status. Using an existing telecommunication infrastructure reduces building costs and frees patients from the expense of introducing networking services. As proof of the concept's applicability, we tested the remote monitoring of heart rate and respiration. The system was tested in real home-visit rehabilitation environments and was found to be useful both for the therapist and the patients in planning and evaluating daily rehabilitation training.

Our telemedicine framework can contribute to preventive medicine. Reduction of medical costs is an urgent issue, especially in Japan where the medical insurance system is in danger of collapse. Total medical expenses can be reduced through supporting home health care management with low-cost devices such as the system discussed in this paper. By creating appropriate rehabilitation plans and incorporating them as a long-term care insurance service, this framework will encourage the development of evidence-based medicine and health care.

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