Development of a Bidirectional Health Support System for the Prevention of Frailty in COPD Patients

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COPD is a lung disease caused by long-term smoking habits and is common among the elderly. COPD is a disease that causes shortness of breath due to bronchiolitis and emphysema. In Japan, there are about 220,000 COPD patients receiving treatment, but it is reported that about 5 million COPD patients have not been examined or diagnosed. Therefore, Ministry of Health, Labour and Welfare has positioned COPD as a major lifestyle-related disease in Japan and has taken comprehensive measures. On the other hand, frailty prevention is important to extend healthy life expectancy, which is a health issue in Japan. Exercise, nutrition, and social activities are important for frailty prevention, and it has been reported that participation in social activities is especially effective for frailty prevention among the elderly.

We decided to develop a remote health support system using smartwatches and smartphones to prevent frailty in COPD patients with a very high frailty incidence. This system mainly provides the following three functions for COPD patients at home. 1) physical health management through online health observation, 2) online exercise therapy through real-time heart rate monitoring, and 3) providing opportunities for remote patient community activities. In this study, we conducted a long-term introduction experiment for six months with 2 COPD patients to verify the functionality of physical health management through online health observation. Based on the data during the system use period, we grasped changes in physical activity and physical condition that were affected by the season and the patient's lifestyle. Based on the results, this system added a function to detect an emergency when a patient is unwell and send an alert to the patient and the supporter. The alert criteria for this function can be set based on the patient's data for two consecutive weeks. In other study, we conducted an experiment to introduce online exercise therapy using a Web conferencing system for 2 healthy adults. As a result, the instructor was able to make the subjects exercise safely while grasping the pulse fluctuation during exercise in real time. The goal of the next step is to build a bidirectional health support system between the patient and supporter using ICT, instead of unidirectional health support from supporter to patient.

Keywords: *COPD, Frailty, Remote, Health Support, ICT*

Introduction

Chronic obstructive pulmonary disease (COPD) is a lung disease caused by long-term smoking habits, and its symptoms are common among elderly people [1]. The main symptoms of COPD are dyspnea on exertion and chronic cough and sputum. It is estimated that there are 210 million COPD patients in the world. In 2020, the WHO announced that COPD is the third leading cause of death in the world after ischemic heart disease and stroke. This trend is no exception in Japan. According to a 2001 Nippon COPD Epidemiology study (NICE study), approximately 220,000 COPD patients in Japan are receiving treatment, but approximately 5.7 million patients with COPD symptoms have not been examined or diagnosed [2]. In Health Japan 21 (the second term) Analysis and Assessment Project, implemented in fiscal 2013, COPD was positioned as a major lifestyle-related disease along with cancer, cardiovascular disease, and diabetes [3]. In addition, the Ministry of Health, Labour and Welfare has set a goal of raising awareness of COPD to 80%, and hopes that raising awareness of the disease will lead to early detection and treatment, thereby extending healthy life expectancy and reducing mortality. However, in a survey conducted by Global Initiative for Chronic Obstructive Lung Disease Japan (GOLD Japan) in 2024, the awareness of COPD was only 32.8%, and the expected results have not been achieved [2]. Therefore, Health Japan 21 (the third term) Analysis and Assessment Project, implemented in fiscal 2024, newly indicated the need to take comprehensive measures such as "Prevention of COPD onset, early detection and treatment intervention, and prevention of severe COPD" [3].

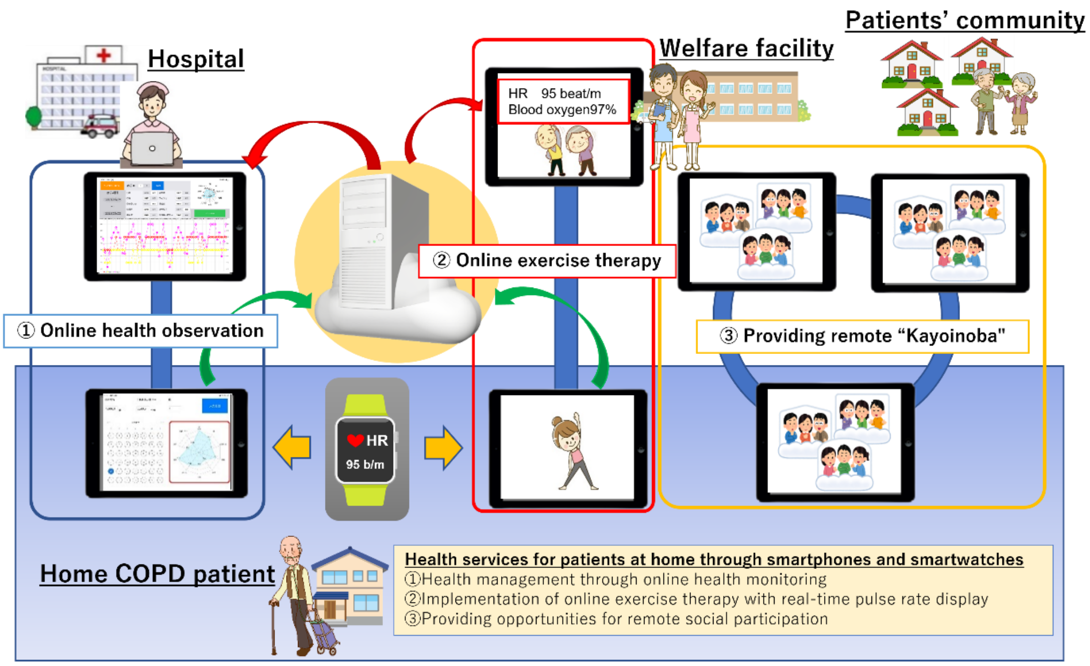

Figure 1. The Outline of the developed bidirectional health support system for the prevention of frailty in COPD patients.

On the other hand, the prevention of frailty, which is an intermediate stage between a healthy state and a state requiring nursing care, is an important issue for extending healthy life expectancy. However, it has been reported that the incidence of frailty is very high in COPD patients, who are often seen in the elderly [4]. Patients with COPD suffer from dyspnea due to the decline in lung function, which reduces their physical activity and their ability to exercise for endurance. This leads to psychological disorders such as physical limitations in activities of daily living and depressive tendencies. As a result, the development of the disease state and the onset of frailty are further promoted while forming a vicious cycle. As a result, COPD patients tend to avoid going out and have fewer opportunities to participate in society. However, it has become clear that social participation, along with exercise and nutrition, has a great impact on frailty prevention as the three pillars of frailty prevention. Therefore, securing social participation opportunities for COPD patients is a major issue.

Purpose

Exercise therapy is effective in controlling the deterioration of the condition and preventing frailty in COPD patients, but the rate of continuous exercise therapy at home is very low [5]. It is considered that the "relationship with people" has an influence as a factor. We reported that recreational activities for COPD patients, which had been held regularly, had to be cancelled due to the spread of the COVID-19, which further reduced the opportunities for patients to go out, resulting in a significant deterioration in patients' social health-related QOL [6].

From these backgrounds, we considered that it is necessary to develop an interactive health support system that realizes "relationship with people" and "connection with society" in addition to the conventional one-way health support from "supporter to patient" such as "management and guidance". Therefore, we decided to develop a remote health support system for elderly COPD patients at home using ICT devices that can realize the following three health support services (Figure 1).

1) Health management through online health observation.
2) Implementation of online exercise therapy with simultaneous display of vital data.
3) Implementation of remote "Kayoi-no-ba".

"Kayoi-no-ba" in Japanese is meant that a place where local residents, including the elderly, take the lead in activities aimed at preventing long-term care and frailty.

Development of the Health Support System

1. Measure & Send Health Condition and Physical Activity Data 'APP for Patients'

We have developed a remote monitoring system for the health status and physical activity of elderly COPD patients at home. With this system, supporters such as doctors, nurses, and caregivers can not only grasp the daily health status of the patients, but also evaluate the health status and physical activity of the patients long-term and provide health support tailored to each patient. The system in outlined in Figure 2.

In this system, an iPhone and an Apple Watch (Apple, Cupertino, California, USA) are used as patient devices. The OS used for application development was iPhone OS 14 Xcode 13.0, and Swift 5.5 was used for software development. How to operate the patient application is as follows:

1) Resting pulse rate and blood oxygen wellness (oxygen level taken into the blood) are measured

using the existing Apple Watch app, and the data is synchronized to the iPhone.

2) The six-item symptom assessment test (Cough, sputum, stuffiness, sleep, appetite, and vitality) is entered using the iPhone app, and the data is sent to the data server.
3) The results of the symptom assessment test are displayed graphically using the calendar function.

The six-item symptom assessment items are based on questions commonly used by doctors and nurses who treat COPD (Table 1). The ratings for each of the six assessment items (from 0 to 5) were added and multiplied by 20, and then divided by the number of items, i.e., six, to obtain the value of the Total Health Index.

Because the users of this system are elderly COPD patients, we designed it to minimize the amount of information displayed on the smartphone screen and to make the operation as simple as possible.

Figure 2. The Outline of the developed remote health monitoring and support system for patient.

Table 1. Six assessment items in the COPD symptoms questionnaire.

Subject	Sex	Age (y)	Height (cm)	Weight (kg)	BMI	Pulmonary Function Stage
Patient A	Male	77	162	62	23.6	II(moderate)
Patient B	Male	80	163	77.5	29.2	II(moderate)

2. Remote Check and Assessment of Patient's Health Condition 'APP for Support Staff'

First, we built a network server to store data sent from patients' iPhones. Then, we developed a remote system for monitoring the health condition and providing home

Table 2. Participant characteristics and stage of the patients.

Good Condition	Levels	Poor Condition
I don't have a cough	5/4/3/2/1/0	I am always coughing
I don't have any phlegm	5/4/3/2/1/0	I always have phlegm
I have no difficulty breathing	5/4/3/2/1/0	I have great difficulty breathing
I am sleeping well	5/4/3/2/1/0	I can't sleep well because of my lungs
I am eating well	5/4/3/2/1/0	I can't sleet well because of my lungs
I feel very good	5/4/3/2/1/0	I do not feel well at all

health care support for elderly patients with COPD. The system in outlined in Figure 3.

The device used for this system is an iPad (Apple, Cupertino, California, USA). Supporters can use the iPad to retrieve data of the patients they manage from the network server, and check the results of their health observations and physical activity in graphs displayed on the screen. They can also download the data as a CSV file. The operation of the application for supporters is as follows.

1) Select the ID of the patient to be checked, the period for which the data is displayed, and the symptom evaluation items to be displayed.
2) The results of the health observation on the day of viewing are displayed as a radar chart.
3) The data for the specified period is displayed as a time-series graph.
4) Download the patient data as a CSV file from a PC.

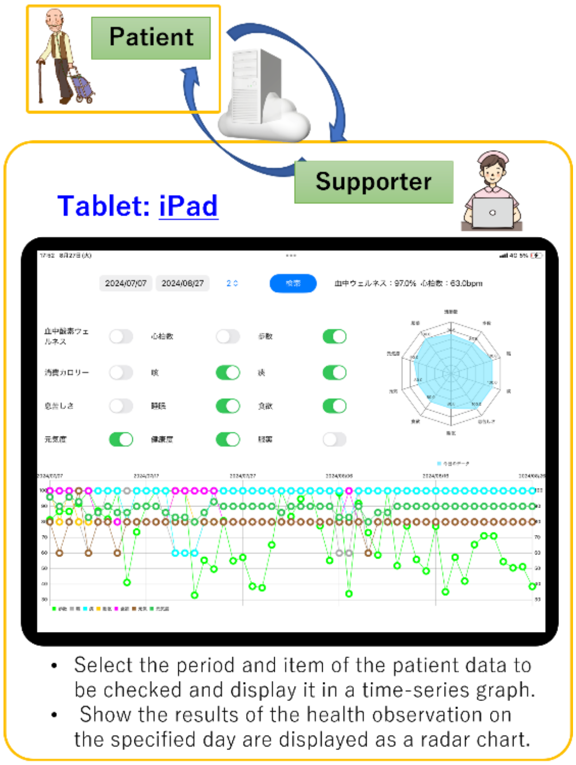

Figure 3. The Outline of the developed remote health monitoring and support system for supporters.

Methods of Experimental Observation and Practical Assessment of the System

This study was approved by the ethics committees of Toyama University, National Institute of Technology, Toyama College, National Hospital Organization Higashinagano Hospital, and Iizuka Municipal Hospital. A long-term implementation experiment of a remote monitoring system of health condition and physical activity using iPhone and Apple Watch was conducted for six months, from July 2024 to December 2024, with patients who were informed about the study and agreed to participate in the study. The subjects were a 77-year-old man with COPD (patient A) and an 80-year-old man with COPD (patient B). The two patients visited the hospital once a month, but their condition was stable and there were no problems in daily life. Neither patient was receiving home oxygen therapy. The physical characteristics and stage of the patients are shown in Table 2.

In the preliminary explanation of the experiment, the patients were instructed how to operate the devices, and they were asked to wear an Apple Watch and conduct a symptom assessment test with an iPhone every day, and also to wear a Lifecorder pedometer (Suzuken, Nagoya, Japan) on their lower back every day to evaluate their daily physical activity time (Figure 4). In this experiment, the patients' data were monitored and evaluated by us using an iPad, not by their doctor, and the results were reported to their doctor once a month.

Figure 4. The photo of right side in the body of "Life Coder" (LC) and the photo of left side is a state of waring LC on side of waist.

Statistical Processing

An unpaired one-way analysis of variance was performed to compare monthly means of physical activity per day measured by the Lifecorder pedometer and the symptom assessment data by the smartphone application, followed by multiple comparisons using the Tukey method for equal variance and the Games-Howell method for unequal variance. Unpaired T-tests were used to compare mean values between days of high and low total health index. The significance level was set at 5%. IBM SPSS 28 Statistics Base was used for all statistical processing.

Results

The utilization rate of the remote health monitoring system was 134 out of 167 days (80.2%) for patient A, and 162 out of 181 days (89.5%) for patient B. Although both patients were elderly, the system utilization rate was high. For patient B in particular, the data could not be transmitted for 15 days until we checked the device due to a malfunction of the Apple Watch, so the system utilization rate would be 97.8% if that period was removed. Seasonal variations were observed in the physical activity per day and the total health index during the system utilization period (Figure 5).

Based on the average value of the total health index during the period, we classified the days with a higher value and those with a lower value than the average value, and compared the average values between the days with a higher value and those with a lower value. As a result, there was no significant difference between the days with high and low health in the item of "stuffiness" among the six symptom evaluation items for both patients, but the average value on the days with a higher value was significantly higher than the average value on the days with a lower value in the other items (Cough, sputum, appetite, sleep, and vitality). This may have been because both patients were not receiving home oxygen therapy and were in moderate condition, and their dyspnea symptoms could be controlled with inhaled bronchodilators in their normal lives.

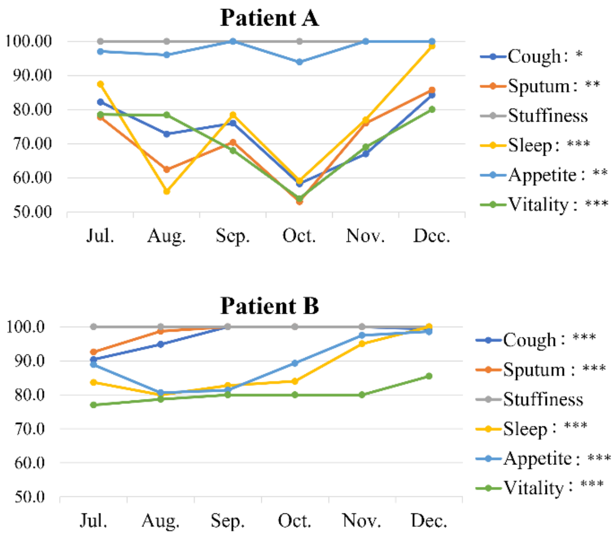

Figure 5. Seasonal changes in symptoms in COPD patients. The graph plots the monthly mean of symptom endpoints. The monthly mean of symptom endpoints was analyzed by ANOVA. *; P <0.05, **; P <0.01, ***; P <0.0001.

Discussion

In recent years, the development and spread of ICT has enabled us to enjoy various benefits in our lives. However, on the other hand, the digital divide between those who can benefit from ICT and those who cannot has become a social problem. It is said that there are four levels of the digital divide: 1) the gap in the ownership of information media, 2) the gap in the ability to use functions, 3) the gap in the use of cyberspace, and 4) the gap in the ability to process information. The users of the health support system constructed in this study are the elderly, which is the age group most vulnerable to the digital divide [7]. Therefore, in creating the application, we particularly emphasized the simplification of the application operation and the simplification of the display screen in order to eliminate the gap in 2) the ability to use functions. The implementation experiment of the system was conducted with 2 elderly COPD patients, and since their use rate of the system was high, we believe that the operability of the system was appropriate for the elderly. However, in order to promote the social implementation of this system in the future, it is necessary to consider other solutions for the digital divide.

The patients' total health index data collected by the smartphone application were classified into high and low health days, and the six symptom evaluation items were compared. There were significant differences in five symptoms except for "stuffiness". Furthermore, when we compared each item, for patient A, the smallest difference in points between high and low health days was vitality (8.6 points), and the largest difference was sleep (28.9 points). For patient B, the item with the smallest difference was phlegm (2.1 points), and the largest difference was appetite (15.7 points). By monitoring the health status of the patients for six months, we were able to capture changes in physical activity and symptoms from a long-term perspective for each patient. Therefore, we believe that grasping the long-term changes in individual patients' symptoms can be useful information for future treatment and rehabilitation (Figure 6).

In addition, during six months of monitoring the health status of COPD patients at home, we were able to confirm days when symptoms were strong or physical activity was markedly reduced (Figure 7). Therefore, we attempted to add a new function to this remote health support system. It is a function that issues an alert to a patient's and supporters' devices when a patient feels unwell. By analyzing the pattern of individual changes in their physical condition over a long period of time, the system detects sudden unwell conditions and issues an alert, thereby providing an early response to unwell conditions such as acute exacerbations. As the population ages further in the future, we believe that telemedicine will develop to eliminate medical disparities by region and improve medical access for patients who have difficulty going to hospital. The alert function added in this study is expected to increase its utility value as a function that foresees such a future.

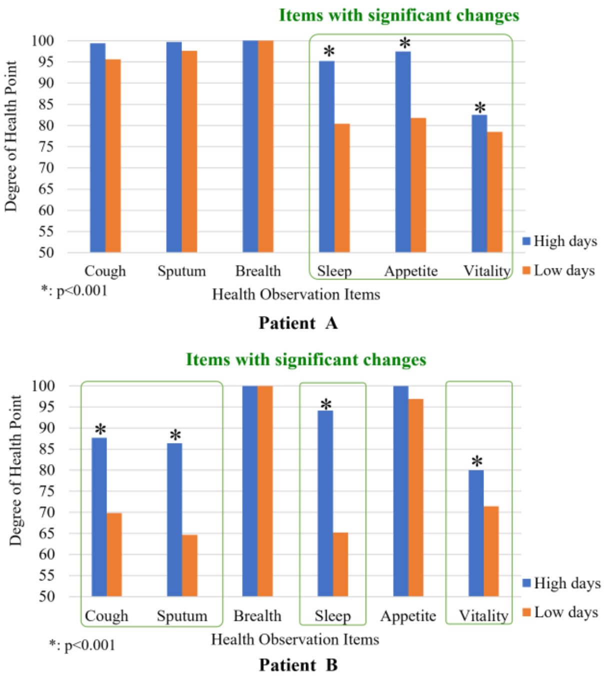

Figure 6. Individual Differences in symptom Changes in COPD patients. The graph shows the mean values of symptom evaluation items divided into days with high and low health. Comparison of mean values of symptom evaluation items was analyzed by T-test. *; P <0.0001.

Conclusions

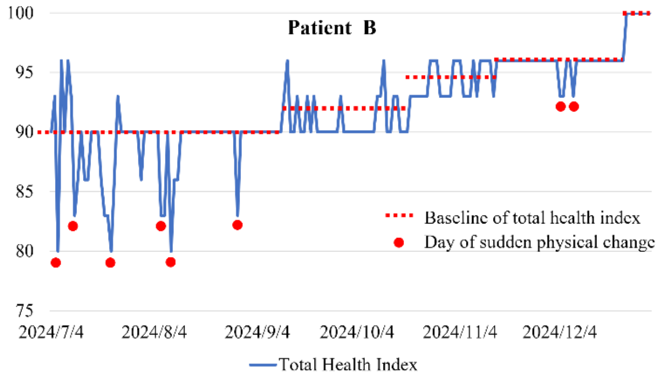

Figure 7. Days of poor health based on seasonal changes in Total health index.

In this study, we constructed a remote health support system for elderly COPD patients at home, and implemented a part of the system that remotely monitors the health status and physical activity of COPD patients at home. By accumulating patient data over a long period of time, we were able to grasp the actual condition of each patient, and found the possibility of providing health support that matches the symptoms and lifestyle of each patient. In addition, we assumed that the users of this system were elderly, and devised the device operation method and screen display method. In this six-month experiment, the use rate of the system by the patients was high, and it seems that this system also addresses the information gap regarding the ability to use the functions.

In the future, we will try to implement this system in society. And, we will aim for a society without information gap in the health promotion of the elderly at home.

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