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# Development of Lifelog Sharing System for Rheumatoid Arthritis Patients using Smartphone

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*Abstract*—**In this paper, we report the development of a lifelog sharing system for rheumatoid arthritis patients. Our system can objectively assess patients' condition from day to day via their smartphone use. We conducted a field experiment to investigate the feasibility of lifelog collection and sharing. The rate of patient assessment is very high. The system collects daily change in patients' activity as influenced by the disease.**

## I. Introduction

Rheumatoid arthritis (RA) affects approximately 1% of adults and has been recognized as one of the most serious rheumatologic conditions in the developed world [1]. RA is a progressive inflammatory disease that causes multiple associated joint problems, decline in functional status, and premature mortality [2] [3]. Treatment comprises medication to control inflammation and multidisciplinary interventions to reduce symptoms and maximize self-management [4].

Because the expressed symptoms of RA fluctuates from day to day, there is necessary to closely monitor the patients' health. Most traditional methods recording the patients' subjective assessment on paper. These methods lack objectivity and cannot catch subtle changes from day to day. Effective and frequent objective assessments are necessary.

We focus on gait analysis for the objective assessment of RA. RA leads to functional disability and changes in normal gait patterns are common, a common but clinically serious problem that substantially affects RA patients' quality of life [5]. Previous studies have demonstrated that RA may lead to a decreased walking speed [6], shortened stride length, and increased double-stance periods [7], indicative of a limitation in lower limb function. Recently, wireless tri-axial accelerometers have become widely used for gait analysis, because they are easy to use, are inexpensive, and do not require a laboratory environment. Several authors have performed gait assessment using such accelerometers in a clinical setting, including in patients with stroke, patients with Parkinson's disease, and older adults [8][9][10].

Smartphones have recently become widely used as self-management or rehabilitation tools for heart failure [11], diabetes management [12], and pulmonary rehabilitation [13]. Smartphones have become ubiquitous devices, are now less expensive, and can save large amounts of data and convey these data via both wireless transmission and e-mail. Our previous studies, furthermore, indicated that the smartphone accelerometer has the capacity to measure gait parameters accurately[14], and disease activity of RA was significantly associated with the gait parameters recorded by the smartphone[15].

The advantage of using smartphones is not only getting objective assessments but also permit the easy sharing of daily health and activity information among the patient and health professions. But using smartphones has two major problems. One is usability; most RA patients are advanced in age with low IT literacy. Another is psychological resistance (includes privacy concerns) to sharing information.

We designed and implemented a new lifelog sharing system linking RA patients and health professions. This system collects patients' subjective and objective assessments from the lifelog on the smartphone. This paper presents system design and evaluation in a field experiment.

## II. System Design

### A. Overview of the system

Fig. 1 shows our system's overview. Each patient has a smartphone running an application for data collection. The smartphone sends the data to server via the Internet. Data are stored in server as lifelogs. Health professionals view the lifelogs of patients by accessing the server. Patients can view their own lifelog using their smartphone at any time.

Fig. 2 shows main menu of our smartphone application. Patients can measure gait and record their physical condition and taking medicine. They also can view their data.

### B. Gait Analysis

Linear trunk accelerations are gathered by the participants' smartphones (kept in a waist pouch) as they walked for 10 seconds at their preferred speed. Fig.2 shows gait measurement screens. The recorded acceleration signals were analyzed within the smartphone in our system, but the gait analysis can be implemented in the server.

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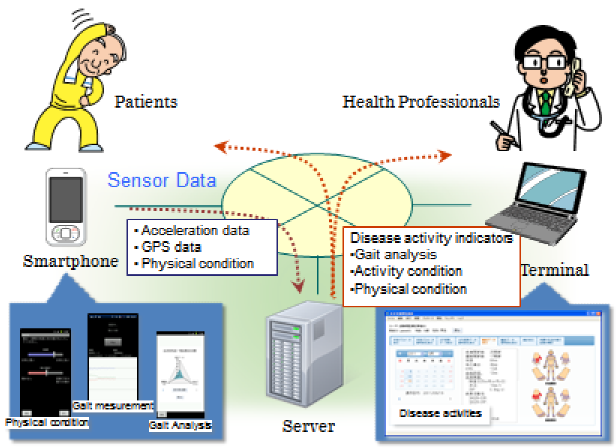


Figure 1. System overview

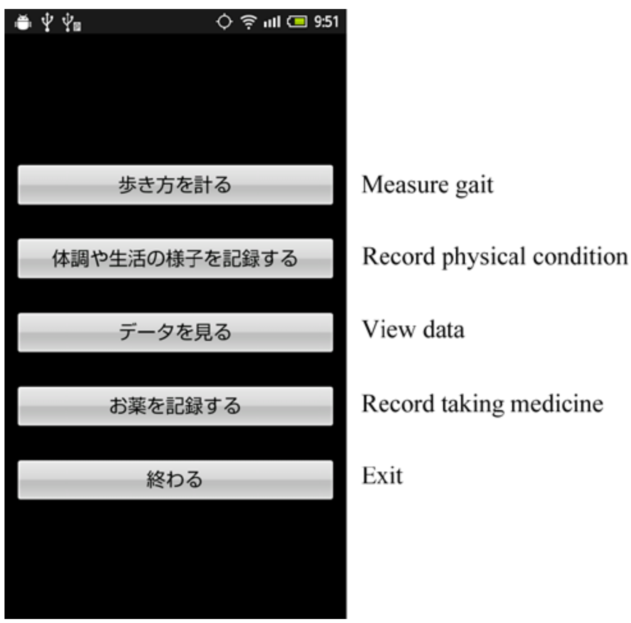


Figure 2. Main menu of smartphone application
(Right side is English Translation)


Figure 3. Gait mesurement screens
Left: start screen (left button is start, right is exit), Center: count down screen (measurement starts 8 seconds after, Right: mesurement screen (measurement ends 8 seconds after).

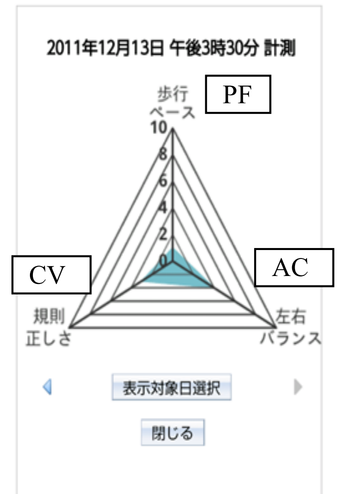


Figure 4. Gait result screen

The following gait parameters were calculated in accordance with previous studies: peak frequency (PF), autocorrelation peak (AC), and coefficient of variance (CV) of the acceleration peak intervals. The PF value indicates the gait cycle, which is the time taken for 1 step. The AC value indicates the degree of gait balance, so a higher AC value indicates a greater degree of balance. The CV value indicates the degree of gait variability, i.e., the variability in the elapsed time between the first contacts of 2 consecutive footfalls. Our previous research indicated that a smartphone with the gait analysis application could measure gait parameters with the same accuracy as the conventional tri-axial accelerometer [14]. The calculation methods of these gait parameters are detailed in our previous studies [14][15].

Fig. 4 shows the gait result screen. Patients can view their gait analysis result through “view data” button on the main menu of smartphone application.

*C. Measurements with the smartphone application*

The modified health assessment questionnaire (mHAQ), self-assessed tender joint count (sTJC), and self-assessed swollen joint count (sSJC) were added to our smartphone application. All of these data were entered via a touchscreen questionnaire by the participants themselves. mHAQ is a self-reported measure of physical function. It is a widely used and validated tool to quantify RA functional disability [16][17][18][19]. The mHAQ disability index covers 8 activities of daily living (ADL), including dressing and grooming, rising, eating, walking, hygiene, reach, grip, and community activities. mHAQ uses a scale ranging from 0 to 3, where 0 = no disability and 3 = severe functional disability. Our smartphone application (Fig. 5) gathered data on the 49 (sTJC) or 46 (sSJC) joints defined by American College of Rheumatology (ACR) [20].

General health condition and pain condition were recorded on the smartphone using a visual analog scale (VAS). VAS is a tool used to help a patient rate the intensity of certain sensations and feelings, such as pain. The visual analog scale for pain is a straight line graded from no pain (left) to worst pain imaginable (right) (Fig. 6). A patient marks a point that matches the amount of pain he or she feels

To quantify daily activity of the participants we use the GPS service of the smartphone. To let battery last a long time our application got GPS signal every three minutes. We register the latitude/longitude of the patients' home and calculate total movement distance and range of movement from patients' home. For privacy protection, the health professions cannot view the raw GPS data.

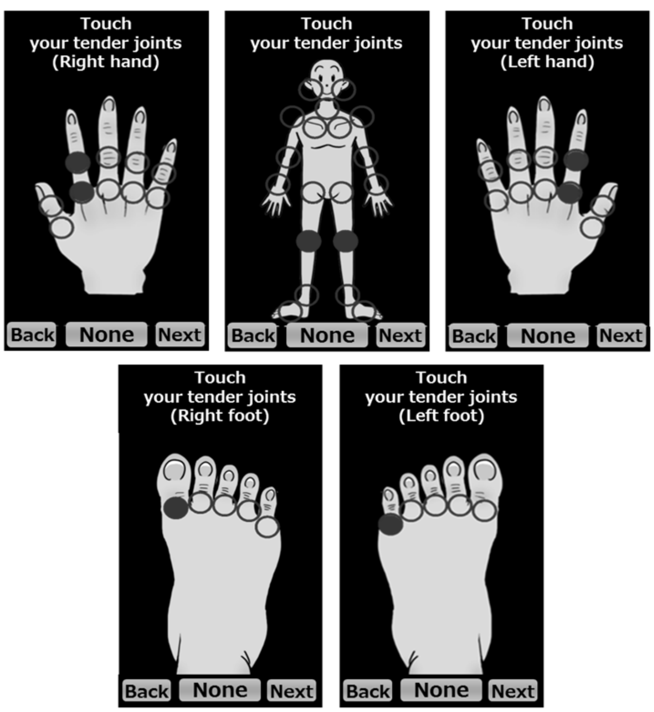


Figure 5. Screen of inputting the number of tender joints and swollen joints (simillar screen). Patients assess their tender joint count and swollen joint count in accrdance with the 49 or 46 joints used by the ACR and touch the pertinent joints on the screen.
(Screen text is English translation.)

## III. Field Experiment

We started this field experiment from February 2012. The participants were 19 RA patients (mean age, 54.8 ± 11.5 years) who attended the rheumatology outpatient clinic of Kyoto University Hospital. All participants are female. Patients with RA as defined by the American College of Rheumatology 1987 or 2010 criteria were included. We excluded patients based on the following exclusion criteria: other musculoskeletal disorders, cognitive disorders, Parkinson's disease, stroke, or unable to walk over 10 m unassisted. Patients with previous surgery in the lower extremities were also excluded. The patients' medications were not changed during the study period.

The smartphone (dimensions: 119 mm × 60 mm ×10.9 mm; weight: 121 g; AQUOS PHONE f SH-13C; Android 2.3; Sharp Co., Osaka, Japan) used in this experiment included an acceleration sensor, a recording device, and an application for processing the acceleration signals. We also installed an application in the smartphone that allowed patients to measure their daily RA parameters using the application by themselves.

We obtained written informed consent from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine (approval number E1222) and the Declaration of Human Rights, Helsinki, 1975.

Each patient measured gait and input general health condition and pain once a day, and input mHAQ, sTJC and sSJC once a week. Experiment duration was until the next hospital visit (mean duration, 35.5 ± 11.3 days).

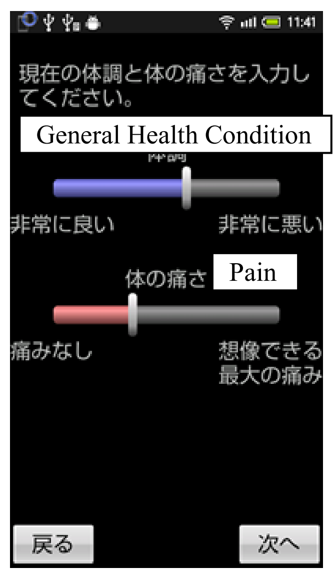


Figure 6. General health condition and pain input screen

## IV. Results and Discussion

The rate of executing gait measurement (once a day) was 81.9% and input rate of mHAQ, sTJC and sSJC (once a week) was 89.3%. These rates are better than we expected because many participants had no experience in operating smartphone. This means the usability problem can be overcome by appropriately designing the application; most patients were very concerned about their disease. “Too busy” was the main reason of failure to perform the tasks.

We submitted questionnaires at the end of the experiment. It offered five grades of psychological resistance to lifelog sharing. All patients scored three or below (5 is very high, 1 is very low). This means that patients have little objection if the intended purpose is definite.

Health professionals can integrate the daily objective assessments with blood tests and medication situation. These data will be the basis for the development of more effective treatments.

## V. Conclusion

We reported the development of lifelog sharing system for rheumatoid arthritis patients. Our system can gather objective data from patients on a day to day basis via a smartphone. We confirmed the feasibility of lifelog collection and sharing through a field experiment. The rate of patient compliance was very high. The system captured the daily change in patients’ disease status.

We implemented a feedback function in this system to maximize self-management and are evaluating it in another field experiment.

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