

# Daily assessment of rheumatoid arthritis disease activity using a smartphone application: Development and 3-month feasibility study

Shu Nishiguchi\*, Hiromu Ito,  
Minoru Yamada, Hiroyuki  
Yoshitomi, Moritoshi Furu,  
Tomoki Aoyama, Tadao  
Tsuboyama

Graduate School of Medicine,  
Kyoto University

53 Kawahara-cho, Shogoin, Sakyo-ku,  
Kyoto 606-8507, Japan

\* nishiguchi.shu.82s@st.kyoto-  
u.ac.jp

Tatsuaki Ito, Akio Shinohara,  
Tetsuya Ura

NTT Service Evolution Laboratories  
1-1 Hikarinooka, Yokosuka-shi,  
Kanagawa 239-0847, Japan

Kazuya Okamoto

Division of Medical Information  
Technology & Administration Planning,  
Kyoto University Hospital  
54, Kawahara-cho, Shogoin, Sakyo-ku,  
Kyoto 606-8507, Japan

## ABSTRACT

In this paper, we report the development and feasibility of a daily assessment system for rheumatoid arthritis (RA) patients based on a smartphone application. We measured daily disease activity in 9 RA patients who used the smartphone application for a period of 3 months. A disease activity score (DAS28) predictive model was used and feedback comments relating to disease activity were shown to patients via the smartphone application each day. The disease activity measured by the application correlated well with the patients' actual disease activity during the 3-month period, as assessed by clinical examination. Furthermore, most participants gave favorable responses to a questionnaire administered at the end of the 3-month period containing questions relating to the ease of use and usefulness of the system. The results of this feasibility study indicate that the DAS28 predictive model can longitudinally predict a disease activity score based on the C-reactive protein level and may be an acceptable and useful tool for the assessment of RA disease activity for both patients and healthcare providers.

## Keywords

Rheumatoid arthritis, Disease activity, Smartphone, Self-assessment, Feasibility study

## 1. INTRODUCTION

Rheumatoid arthritis (RA) is a progressive inflammatory disease that causes damage to multiple joints, decline in functional status, and premature mortality [1, 2]. Treatment comprises medication to control inflammation and multidisciplinary

interventions aimed at reducing symptoms and maximizing self-management [3]. Because the symptoms experienced by RA patients fluctuate, close monitoring is required. Traditional monitoring methods involve recording patients' subjective assessments on paper. These methods lack objectivity and are not capable of recording subtle changes that occur daily. Effective and frequent objective assessments are necessary.

Over recent years, smartphones have become ubiquitous in developed countries, are now less expensive than previously, and can save large amounts of data and convey these data via both wireless transmission and e-mail. Based on this, we hypothesized that patients with RA may be able to easily self-monitor their daily disease activity at home using their smartphone. We developed a novel method to assess RA disease activity via smartphones, without the need for laboratory tests or visits to a doctor [4]. We focused on joint symptoms, activities of daily living (ADL), and gait parameters as daily and non-invasive measurements that predict disease activity. Previous studies indicated that the accelerometers contained in smartphones can measure gait parameters accurately [5], and RA disease activity was significantly associated with the gait parameters recorded by smartphones [6]. Furthermore, non-invasive self-assessment of a combination of joint symptoms, limitations of ADL, and walking ability via a smartphone application can adequately predict RA disease activity [7].

Here, we report a longitudinal trial of this self-assessment system. The purpose of this study was to investigate the feasibility of a daily assessment system for RA patients using a smartphone application.

## 2. METHODS

### 2.1 Subjects

The participants were 10 RA outpatients at the rheumatology outpatient clinic of Kyoto University Hospital. All enrolled participants had RA as defined by the American College of Rheumatology 1987 or 2010 criteria. We excluded patients based on the following exclusion criteria: the presence of other musculoskeletal disorders, cognitive disorders, Parkinson's

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disease, stroke, or inability to walk unassisted for >15 m without using walking aids. Patients who had previously undergone surgery on the lower extremities were also excluded. Patients' medications were not changed during the study period. One participant withdrew from the study because of difficulty using the smartphone. Nine participants were therefore included in the trial and final analysis.

The smartphones (dimensions: 119 × 60 × 10.9 mm; weight: 121 g; AQUOS PHONE f SH-13C; Android 2.3; Sharp Co., Osaka, Japan) used in this study 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 themselves using the application over a 3-month period.

Written informed consent was obtained from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine.

## 2.2 Measuring daily disease activity using a smartphone

Our previous study showed that it is possible to measure disease activity score (DAS28) using a smartphone application [7]. The DAS28 predictive model consists of subjective measurements such as tender joint counts (TJC) and the modified health assessment questionnaire (mHAQ) [8], and objective gait balance measurements.

Self-assessed TJC and mHAQ were recorded on a smartphone application that we developed. Measurements were recorded via a touchscreen questionnaire on the smartphone. The TJC was reported according to 49 joints used by American College of Rheumatology in a smartphone application. The mHAQ disability index assesses 8 ADL, including dressing and grooming, rising, eating, walking, hygiene, reach, grip, and community activities. The mHAQ is expressed on a scale ranging from 0 to 3, where 0 = no disability and 3 = severe functional disability.

Participants were instructed to walk along a 15-m walkway at their preferred speed every day, wearing their usual walking shoes, avoiding high heels and hard-soled shoes. Trunk linear accelerations were measured by the participants as they walked on the walkway using the smartphone. The autocorrelation peak (AC) was then calculated as the gait parameter of the degree of gait balance, according to previous studies [9]. All measures were self-recorded by participants daily for 3 months.

The DAS28 predictive model was calculated as the following formula using the results of regression analysis: the DAS28 predictive model =  $2.380 + (0.110 \times \text{TJC}) + (0.080 \times \text{mHAQ}) + (-1.187 \times \text{AC})$ . The details of the data measurement algorithms used in the system have been described previously [7].

## 2.3 Daily disease activity feedback system

Based the DAS28 measured by participants' smartphones each day, daily feedback comments about their disease activity were automatically shown on the smartphone screen following self-assessment. After this, their measurements and the disease activity comments were automatically sent to rheumatologists.

Comments altered according to the mean value of the measurements from the previous 3 days. If the DAS28 was 0.6

points lower than the mean value of the preceding 3 days, positive comments were shown (e.g. Disease activity is well controlled today. You can go out actively). If the difference between the DAS28 of a certain day and the mean value of the preceding 3 days was <0.6 points, comments indicating maintenance of the status quo were shown (e.g. Disease activity is relatively good today. You can live your life as usual). If the DAS28 predictive model score on a certain day was 0.6 points higher than the mean value of the preceding 3 days, negative comments were shown (Figure 1).

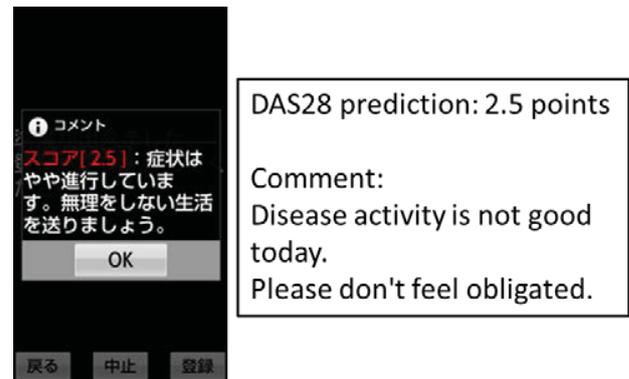


Figure 1: Simulation of the smartphone touchscreen for daily feedback comments (negative comment)

## 2.4 RA disease activity

To assess participants' RA disease activity, the DAS28 based on the C-reactive protein level (DAS28-CRP) [10] (the instrument usually used to measure RA disease activity) was measured by a rheumatologist during monthly clinical visits. The DAS28-CRP includes 4 parameters: TJC, swollen joint count, serum C-reactive protein level, and patient's global assessment of disease status using a visual-analogue scale. The DAS28 is a generally accepted reliable, valid, and responsive measure of disease activity in patients with RA [11-13].

## 3. RESULTS & DISCUSSIONS

### 3.1 Demographic and clinical characteristics of participants

Table 1 shows the demographic and clinical characteristics of participants. The participants were relatively elderly and had established disease with a mean duration of 10.6 years. Despite this, the mean DAS28-CRP was 2.26, and most of the participants had well-controlled disease.

Table 1: Demographic and clinical characteristics of study participants

	mean ± SD
Age (y)	56.6 ± 13.9
Female (n)	8
Height (cm)	159.1 ± 9.2
Weight (kg)	55.4 ± 10.2
Disease duration (y)	10.6 ± 8.3
DAS28-CRP	2.26 ± 1.19
Abbreviations:	
DAS = disease activity score	

### 3.2 Relationship between DAS28-CRP and the DAS28 predictive model score in study participants

Figure 2 shows the relationship between DAS28-CRP and the DAS28 predictive model over the 3-month period. One participant was removed because the blood data for 2nd month was not measured. Figure 2 shows the DAS28-CRP score during the monthly clinical visit and DAS28 predictive model score on the same day. There are therefore 4 data points for each subject and there is a dashed line as the regression line in figure 2. Daily disease activity as measured via smartphone was well correlated with actual disease activity over the 3-month period.

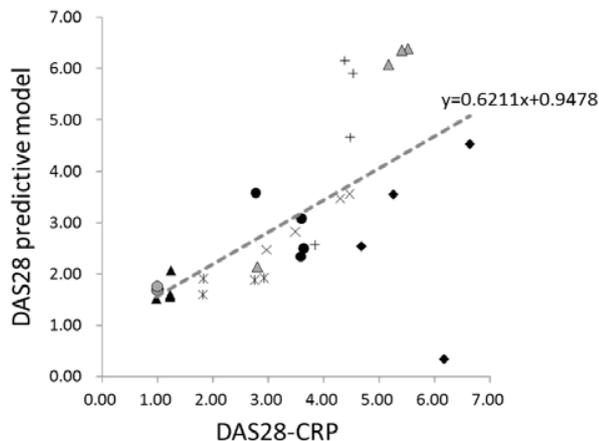


Figure 2: Relationship between DAS28-CRP and the DAS28 predictive model in study participants (4 time points per participant) (n=8)

### 3.3 Questionnaire following the 3-month observation period

After the 3-month observation period, we carried out a questionnaire survey to investigate participants' opinions on the disease activity monitoring system. The results of the questionnaire study are shown below. Most participants gave favorable responses to the 4 questions.

Q1) Could you record your body condition and your life every day?

- i) No problem. (n=8)
- ii) I could record with little problem. (n=1)
- iii) I could not record. (n=0)

Q2) Did you feel the feedbacks of the system suitable to your body condition?

- i) Very suitable. (n=7)
- ii) To some extent. (n=2)
- iii) Some feedbacks were suitable, but some were not. (n=0)
- iv) Not very suitable. (n=0)
- v) Not suitable at all. (n=0)

Q3) Were the feedbacks helpful for you to live your life?

- i) Very helpful. (n=0)
- ii) Helpful. (n=6)

- iii) Some feedbacks were suitable, but some were not. (n=3)
- iv) To some extent. (n=0)
- v) Not helpful at all. (n=0)

Q4) Did you feel nervous or confident to share information (about gait and body condition) with doctors?

- i) Very confident. (n=2)
- ii) Confident. (n=7)
- iii) Neither confident nor nervous. (n=0)
- iv) A little nervous. (n=0)
- v) Very nervous. (n=0)

### 3.4 Future prospects

Self-management is an important treatment option for patients with RA, and has been previously investigated [14]. Significant benefits have been observed if self-management programs are maintained for >8 years [15], and previous studies have demonstrated the utility of online self-management systems for patients with RA [16] and touchscreen questionnaire systems for patient data collection [17]. Smartphones may be useful self-management devices for patients with RA due to their telecommunication facilities, and the fact that they are now ubiquitous and have multiple features. Using a combination of smartphone devices and our self-assessment system, the availability of web-based interventions to support the self-management of patients with RA should be further investigated in a study similar to the previous feasibility study for patients with diabetes [18].

## 4. CONCLUSION

The results of this feasibility study indicated that the DAS28 predictive model can longitudinally predict DAS28 and may be an acceptable and useful tool for assessment of RA disease activity for both patients and healthcare providers.

The predictive model in the present study may play an important role for patients with RA in self-management of their disease activity on a daily basis because it offers several benefits. First, the application does not include invasive measurements like blood testing, but daily measurements (joint symptoms, ADL, and gait parameters) that can be made using a smartphone. Second, disease activity can be represented objectively by the gait measurements in the predictive model. Third, medical staff and patients may be able to share information regarding the patient's condition at home in real time using the functions of the smartphone. As a consequence, patients can receive timely advice from their medical providers and seek interventions before acute exacerbation of symptoms.

## 5. ACKNOWLEDGMENTS

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