FitViz: A Personal Informatics Tool for Self-management of Rheumatoid Arthritis

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Abstract. Rheumatoid arthritis (RA) affects 1 in 100 adults in Canada. Self-management of this disease requires that the patients maintain an adequate level of daily physical activity, while not overdoing it; excessive physical activity can be harmful to RA patients. The RA patients receive regular physical activity recommendations from their clinicians, based on the condition of their disease. Current solutions for physical activity monitor do not satisfy the needs of the arthritis patients and their clinicians, as they do not allow the patients and the clinicians to know if the patients did the physical activity as recommended by the clinicians. Therefore, we developed a web application which monitors patient's daily physical activity, and generates visualizations to help the patients in the self-management of the disease. In this paper, we present the design of the application and the interim results of an ongoing pilot study that we are conducting to evaluate our prototype.

1 Introduction

Rheumatoid Arthritis (RA) is a chronic musculoskeletal disease that causes pain, and damage in muscles, and joints, resulting in decreased mobility and decreased functional independence. One of the important factors in successful management of arthritis is maintaining a physically active lifestyle. There is ample evidence that suggests that a physically active lifestyle can reduce pain, improve mobility and quality of life (QoL) [4,10,14,15]. However, patients' adherence to keeping an active lifestyle is poor, with fewer than half of the patients being active [1]. In 2011, the Canadian Community Health Survey reported that over 60% of adult arthritis patients, with age over 30 were physically inactive during their leisure time [13, p. 38].

One of the important contributors to the lack of exercise adherence among arthritis patients is lack of self-efficacy [5,18]. Self-monitoring has been shown to improve self-efficacy. Gleeson-Kreig has shown the effectiveness of self-monitoring in improving self-efficacy among type 2 diabetes patients [6]. In addition to improving self-efficacy, self-monitoring can also lower hospitalization [9] and reduce costs [2].

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While adequate physical activity is necessary, it is also important that the patients do not over-exert themselves. Over-exertion can result in excessive joint pain, which in turn can act as a further barrier to adequate physical activity [5,18]. However, the current consumer-accessible wearable devices such as Fitbit® are not designed for arthritis patients. For instance, Fitbit does not take into account the disease activity of a patient when identifying active minutes. Further, when identifying non-sedentary hours—a feature that was added very recently[1]—requires that everyone, irrespective of their physical ability, perform 250+ steps in an hour.

Every arthritis patient has a different tolerance for physical activity, and different levels of disease activity. Based on their current condition, a clinician can help them set realistic goals that do not hurt them while still maintaining adequate physical activity. In this paper, we present the design of a web application that we have developed to help arthritis patients and clinicians customize goals based on parameters relevant for self-management of arthritis. We also present the intermediate results of an ongoing pilot study.

2 Related Literature

While previous research has focused on using accelerometers in a smartphone for arthritis detection [19] and disease activity prediction [12], there is a lack of research in understanding the effectiveness of physical activity tracking for self-management of patients with rheumatoid arthritis. However, there is previous research that focused on detection of arthritis. For example, Yamada et al. developed a smartphone application for detecting abnormal gait in arthritis patients [19]. However, their research focused on detection of abnormal gait, and not on the self-management.

Physical activity tracking has also been employed for other areas in the health domain. Nachman et al. developed "Jog Falls", a system designed for diabetes patients and their physicians [11]. Jog Falls monitored diet (via manual logging) and energy expenditure and helped the patients and physicians to analyze and reflect on their data. The authors found that Jog Falls was effective for weight loss. Lee et al. developed Asthmon, a ubiquitous toy for children [8]. The toy consisted of a virtual pet and peak flow meter. The virtual pet instructs the child to inhale and exhale, and displays behaviors based on the child's use of the device. Physical activity monitoring has also been used for monitoring mobility recovery in older patients after surgery [3]. However, it was not used for self-management, and used only for monitoring purpose.

Automatic measurement of physical activity is not influenced by reporting bias and issues with patient recalling past information. Therefore, there is a growing interest in using a patient's lifelog data in clinical practice [16]. West et al. conducted a study—literature review and vignette based role-play approach with clinicians—to explore the opportunities and limitations in using life log

[1] https://blog.fitbit.com/sit-less-move-more-with-hourly-activity-stationary-time-tracking, published in April, 2016.

data in clinical settings [17]. One of the findings, relevant to our case, is that the need for visual presentation of information that the clinicians can use to explore patient data. In another research, Kim et al. employed use of food logs and physical activity during a patient–clinician consultation [7]. The authors found that clinicians usefully employed this data to develop and recommend specific plans for their patients.

3 The FitViz App

We consulted with clinicians—3 physiotherapists, one of whom is also an arthritis patient—to determine the physical activity goals and parameters that were important to consider for supporting self-management of arthritis. We found that the clinicians were interested in 3 physical activity goals: number of minutes in a day spent doing bouts (continuous activity sessions of moderate-to-vigorous activity) including sessions of over-exertion, number of non-sedentary hours in a day, and sleep. We designed a prototype which was iteratively modified based on the feedback we received from the clinicians and the patients. The final prototype collected Fitbit data to visualize bouts, sleep, and non-sedentary behavior and allowed a clinician to set daily goals based on the patient's physical current condition.

3.1 Physical Activity Parameters

- **Bout.** A Bout is a session of continuous physical activity (PA), performed with a minimum average intensity for a minimum recommended duration. In addition, a bout can be "longer than recommended" if the patient exceeds the maximum recommended duration, "harder than recommended" if the patient performs the bout with higher than the maximum recommended intensity, and "sooner than recommended" if the patient does not take sufficient rest after the previous bout.
- **Non sedentary hour.** We defined an hour as non-sedentary if it has enough minutes with greater than 10 steps. We used a threshold of 10 steps – instead of 0 steps – because we found that Fitbit often overestimated the number of steps in a minute.

3.2 Clinicians Recommend Customized Patient Plan

When a clinician signs into FitViz, she sees a list of her arthritis patients. The clinician can change the settings that affect the detection of bouts and non-sedentary hour. FitViz allows the clinician to set daily goals for the number of minutes spent during a bout, and the number of non-sedentary hours. In addition, the clinician can adjust other parameters that are used to detect bouts for a patient. These parameters include the minimum and maximum recommended intensity for a bout, minimum and maximum duration for a bout, the duration to rest between bouts, and the minimum number of minutes a patient must

move in an hour for it to be considered a non-sedentary hour. Figure 1 shows the interface that the clinicians can use to set a new plan for a patient. When a clinician moves the sliders the visualization updates to show how changing the parameters affects the visualization.

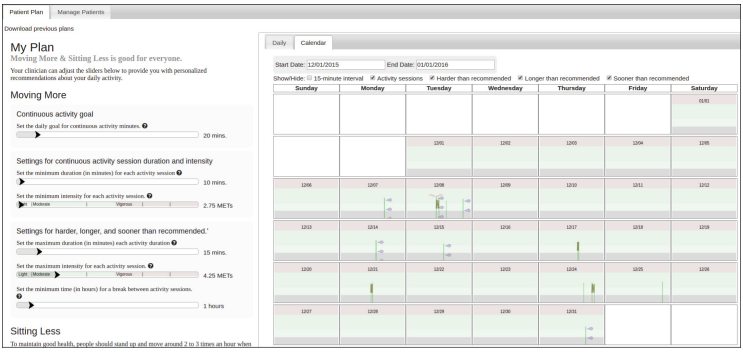

Fig. 1. A clinician can move the sliders to see how it affects the visualization and set a new plan for the patients.

3.3 Visualization of Bouts and Non-sedentary Behavior

When a patient signs into FitViz, she sees a visualization of her daily activities and progress towards her goals (see Fig. 2. The x-axis represents the day as 24 h. The y-axis represents the intensity of physical activity. The bouts are visualized as green bars. When a patient exceeds the recommended maximum intensity or duration during a bout, red heat marks—using a metaphor of radiation—and sweat drops appear on top the green bars respectively. When a patient performs two bouts without taking sufficient rest in between, a spring is drawn between the two green bars. Non-sedentary hours are visualized using a walking icon that appears below the x-axis. In addition, the patient can check her progress towards her daily goals (see Fig. 2(c)).

4 Pilot Study

4.1 Participants

To evaluate our system, we conducted a pilot study with 10 participants who have rheumatoid arthritis. So far 9 participants—8 female, 1 male between ages of 47 and 66—have been recruited and completed the pilot study (Fig. 3).

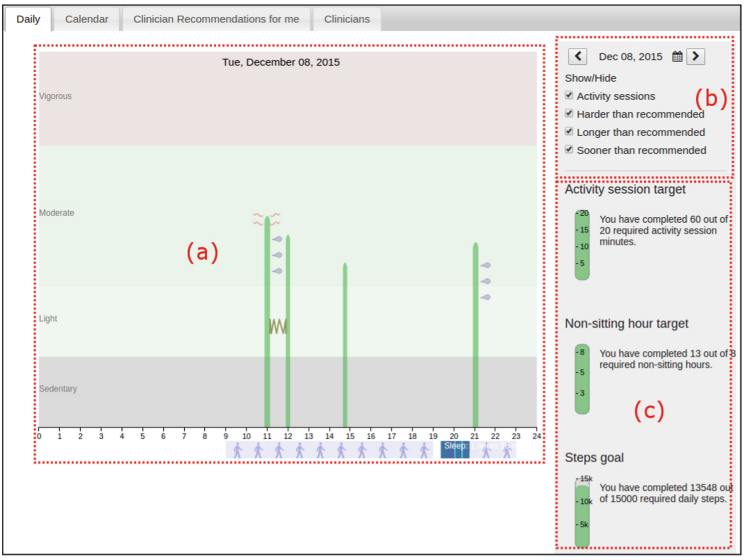

Fig. 2. FitViz Visualization for a single day. (a) Visualization of bouts, non-sedentary hours, and sleep in a day. The width of the bar represents the duration of the PA session, and the height of the bar represents the average intensity level of the physical activity; (b) The patient can change date; (c) Visualizations showing progress towards daily goals of minutes spent doing bouts, non-sedentary hours, and number of steps in a day.

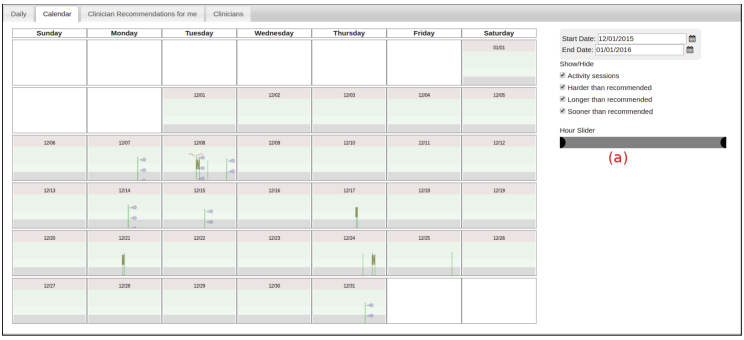

Fig. 3. A patient can select a range of days using the start date, and end date to see bouts performed in the past. (a) An hour range slider allows the patient to select a range of times in a day to visualize.

4.2 Procedure

Before the study, the participants were asked to wear Fitbit Flex for 4 days. This was followed by 1.5 h long education session where they received standardized education from a physiotherapist. The physiotherapist used the data collected

during the 4 days to set goals for the patients. The research staff then setup FitViz and Fitbit for the patients to use. The participants then used FitViz and Fitbit app for 4 weeks. During this time, the participants consulted with their physiotherapist 3 times—in the beginning of the study (face-to-face), and at the end of 2nd and 4th week (over phone). At the end of 4 weeks, the participants filled a questionnaire containing questions from Fatigue Severity Scale, McGill Pain Questionnaire Short Form, and Partners in Health Scale. In addition, they filled a System Usability Score (SUS) form. This was followed by an interview, where the participants were interviewed about the intervention, and their experiences with the orientation session, using the FitViz application, and consultation with the clinicians. In this paper, we report the SUS score, and results from the interviews that are relevant to the design of the application. The interviews are still being transcribed. Therefore we report on the 5 interviews which are completely transcribed.

4.3 Results

All participants found the system engaging. Based on the responses from the 5 participants, who have completed the study, FitViz received a high usability score of 78 (SD = 17.2). We now report on the experiences expressed in the interviews.

Encouragement from Non-sedentary Successes. We found that the participants found the walking icons at the bottom of the visualization were helpful.

"Loved the walkers at the bottom."

"That's one thing that's actually very helpful."

The walking icons which represented the hours spent non-sedentary. Achieving a bout is much more harder than walking enough over an hour. Even if a patient is unable to perform enough bouts during a day due to pain, it is comparatively easier to meet non-sedentary goals. Getting success in keeping non-sedentary was a source of encouragement for the patients to continue moving. Another participant found it encouraging

"that you know you're moving every hour."

Supporting Reflection and Awareness. Visualizations which provide an overview of whether or not a goal was achieved is useful. However, detailed visualizations can be important for reflecting and gaining awareness about self. We found that visualizing bouts and non-sedentary hours over a 24-hour timeline presented an opportunity for the patients to get more aware of their physical activity behavior. One of the participant metnioned

> "Well overall, the Fitbit kind of shows you stuff but if you set your goals, it, it might show you how many steps per goal but as people with arthritis of course we've got other goals like spreading things out, like, like the sitting each hour target. You know that was an eye opener for me is that sometimes I could go two, three hours and, especially with my work, and not necessarily get up, and this was a real reminder for me so and that's something that the Fitbit kinda shows you but doesn't really show you whether you've gotten too, done too much or not enough."

Disregarding Partial Successes Is Discouraging. One of the aspects of FitViz that the participants found frustrating was that FitViz does not recognize bouts even if they are only slightly lower than recommended intensity, duration, or have a break of more than one minute. This is caused due to strictly defined parameters for bout detection. For example, this strictness can result in not identifying a potential bout because the patient walking in an urban area had to stop multiple times at stoplights. One participant said,

> "...it doesn't make sense to me when you're out for half an hour walk and you have to stop at lights, or you stop to do up your shoe or whatever, or you stop for, like that little bit of a stop but that it makes that much of a difference."

5 Conclusion

In this paper, we presented FitViz, a web application to facilitate self-management of arthritis and a data-based communication between the patients and their clinicians. FitViz was successful in enabling reflection and awareness, providing encouragement, and providing objective measurements of physical activity to clinicians. However, there are certain aspects such the calendar view which remained largely unused. Further, we found that strict definitions of success can be discouraging. Our visualizations need to be redesigned to account for partial successes. Another limitation of the system is that is not available on mobile platforms. Mobile platforms can act as better means of encouraging patients to move more and provide immediate feedback. In addition, our pilot did not explore the effect of using FitViz on long-term behavior change. In this pilot, we focused on the feasibility of the application, and understanding its use. In future, we plan to study how FitViz can support long-term behavior change.

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