Proceedings of The National Conference
On Undergraduate Research (NCUR) 2016
University of North Carolina Asheville
Asheville, North Carolina
April 7-9, 2016

Assistive Technology: Mobile App Designed to Prevent Pressure Ulcers

Nam Phung
Department of Computer Science
Swenson College of Science and Engineering
University of Minnesota Duluth
1049 University Dr, Duluth, MN 55812 USA

Faculty Advisor: Dr. Arshia Khan

Abstract

A pressure ulcer is an injury to the skin and underlying tissue resulting from prolonged pressure on the skin. Wheelchair-bound patients have a great chance of developing pressure ulcers due to long time sitting in a wheelchair. The objective of this project is to design a mobile app to help wheelchair-bounded patients prevent pressure ulcers. Secondly, the app is expected to reduce re-admissions, thus, reducing the healthcare cost. The app is also designed to collect data based on patient's exercise records and help promote and support evidence-based practice. The mobile app is designed into two parts: Exercises and education. The app will include three exercises: sideways lean, forward lean, and wheelchair push-ups. It will also have documents instructing patients to prevent pressure ulcers, educating them about the preventive measures, and providing them inspection to proactively monitor the onset of pressure ulcers. The app will also provide patients and therapist with other functions such as communicating with the therapist, setting up the duration of each exercise, notifying the patients to get off the wheelchair to prevent pressure ulcers, and notifying the users to do the exercises. The project is expected to provide patients with a mobile-friendly app that is easy to use. It is also expected to provide therapists with data for further research based on the records collected from the users.

Keywords: Pressure ulcers, decubitus ulcers, mobile app, wheelchair-bound patients

1. Introduction

Bedsores — also called pressure sores or pressure ulcers — are injuries to skin and underlying tissue resulting from prolonged pressure on the skin. Bedsores most often develop on skin that covers bony areas of the body, such as the heels, ankles, hips and tailbone.[1]

It is known that some weight shifting exercises including forward lean, sideways lean, or a wheelchair push-up will result in very large reductions in interface pressure and significant increases in buttock blood flow.[2] Some other methods for preventing pressure ulcers including moisture management, nutrition support, and skin inspection.[3] National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance defines that the skin and tissue assessment is important in pressure ulcer prevention, classification, diagnosis, and treatment.[4]

This study intends to develop an assistive technology to help wheelchair-bound patients perform weight shifting exercises to reduce the chance of developing pressure ulcers. The assistive technology will also provide patients with educational resources to increase knowledge on how to avoid pressure ulcers.

2. Methodology and Results

Mobile devices are now playing an important role in the lives of people and making them depend on the devices. Some advantages of the mobile devices can be easily pointed out such as the small weight, small size, and cheap prices. Mobile apps specifically developed for healthcare industry can be proven as a cheaper method to help reduce health care costs. A mobile app was designed to help wheelchair-bound patients prevent pressure ulcers. The iOS platform was chosen to develop this app using Objective-C language with Xcode as the integrated development environment. The app was later installed on an iPhone 4s device as seen in Figure 1 and was given to the therapist to conduct testing on the patients.

Figure 1 – The iPhone 4s device

The goals of this research project were to verify and test the following hypotheses:

H1: Wheelchair-bound patients who perform weight shifting exercises at regular intervals will reduce the chance of developing pressure ulcers.
H2: The data taken from the patient's exercise log will help clinicians and the patients know how long before pressure ulcers can be developed.

2.1.Phase 1: Early Design Of The Mobile App

The mobile app was designed to have the following features:

- Provide 3 weight shifting exercises to prevent pressure ulcers (Forward lean, sideways lean, and wheelchair push-up).
- Prompting for "Sustained position test" exercise.
- Track the movements of the user using a built-in accelerometer in the mobile device to verify that the user is doing the weight shifting exercises.
- Create a schedule to notify patients to do exercises every 15, 30, or 45 minutes.
- Save the patients exercise log to a cloud server for further research.
- Provide educational resources for preventing pressure ulcers for education and self-prevention.

The app was designed to provide the wheelchair-bound patient with a tool to prevent decubitus ulcers. An accelerometer is a device that measures changes in gravitational acceleration in any device it's installed in. Accelerometers are used to measure acceleration, tilt, and vibration in numerous devices.[5] Because the accelerometer is a built-in instrument that is presented in every mobile device nowadays, it can be used to help track the movement while the patient is doing exercises.

An accelerometer can detect its own acceleration and is used in mobile phones to determine the phone's orientation.[6] The patient was provided with a pouch to put the device inside and wear the pouch around the chest. After that, the user pressed a button in the app to start the exercise. The app used the accelerometer installed in the device to verify

that the patient was exercising. This verification process was done through the tracking of the patient's movement, tilt direction, and acceleration.

After finishing the exercises, the data was saved and stored on the cloud server. This information will give the therapist a deeper understanding of the relationship between the development of decubitus ulcers and the time a person spend sitting in the chair. The algorithm for the mobile app is shown in Figure 2.

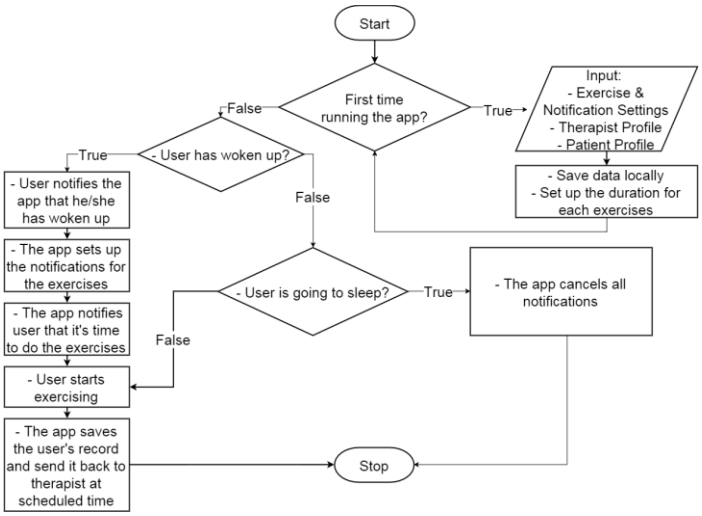

Figure 2 – The algorithm of the app

The features of the app are shown in the figures below:

Fig 3 – Profile of the app user
Fig 4 – Settings for the weight shifting exercises
Fig 5 – Documents for self-preventing pressure ulcers
Fig 6 – Three different weight shifting exercises (Forward lean, sideways lean, and wheelchair push-up)
Fig 7 – Therapist contact

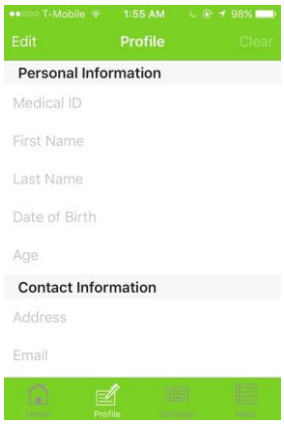

Figure 3

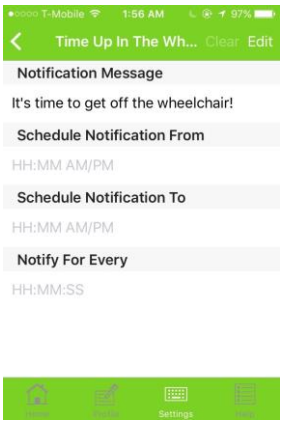

Figure 4

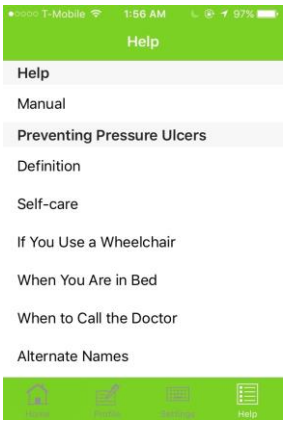

Figure 5

Figure 6

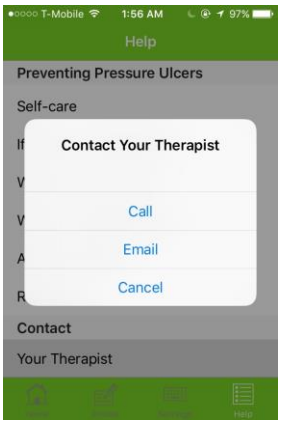

Figure 7

2.2. Phase 2: Re-Design And Further Upgrade

After finishing phase 1, the app was installed on the device and given to the therapist for testing and evaluation on their patients. The evaluation of the app by the therapist provided positive feedback. However, the therapist exposed two major issues after testing the app on the patients.

First, the accelerometer was unable to track the sideways movement of the user. The app could not verify whether the user was doing the sideways shifting exercise or not. Thus, it produced unreliable data that the therapist needed for further research.

Secondly, since the app was not able to figure out if the user is awake or asleep, it was constantly firing notifications and interrupted the patients. This second issue reduced the user-friendliness of the app significantly and made it hard for the patient to use the app.

Therefore, a new solution must be considered to make the app produce reliable data and improve its user-friendliness. For these reasons, instead of using the accelerometer as introduced in phase 1, a wireless pressure map was presented as a solution to these problems.

The solution was to incorporate a pressure mapping mattress wirelessly connected to the mobile app to create a system that can produce more reliable data than the one presented in phase 1. The PS-256 pressure mapping mattress was chosen for this system. The mattress's size is 18"x18" and it contains 256 pressure sensors. The mattress will be put in the wheelchair and it will be connected to the app using the Bluetooth technology.

Figure 8 – The PS-256 pressure mapping mattress

When the patient is doing the exercises, there will be a shift in pressure displayed on the map. This data will be sent back to the app as a matrix of numbers. Each of these numbers represents a pressure value detected by a pressure sensor in the map. A new algorithm will be developed to help detect the shift of pressure from one area of the map to another. Hence, this algorithm will enable the app to verify the user's participation. Figures 9 and 10 show examples of a pressure map and its matrix extracted from the mapping mattress.

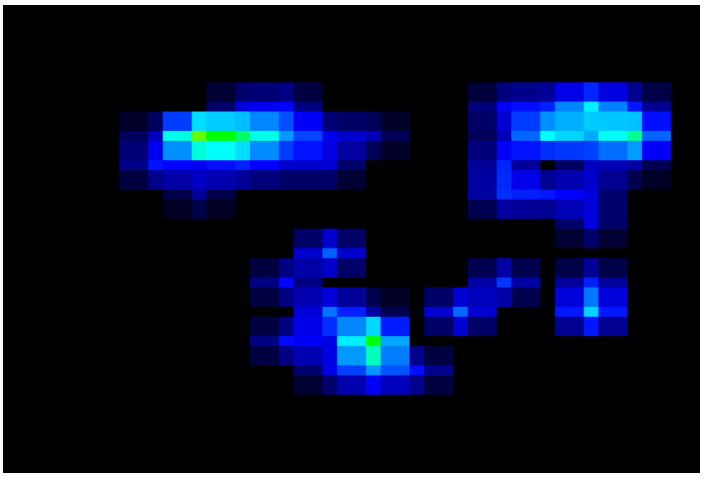

Figure 9 – A pressure map

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	23	27	8	0	0	1	28	30	52	30	0
0	0	0	18	89	69	38	21	19	0	3	20	56	48	78	0
0	0	0	21	22	28	20	19	3	0	11	32	13	24	26	17
0	0	0	8	18	17	16	10	4	0	11	30	33	22	18	15
0	0	0	3	8	13	9	6	6	1	7	6	13	25	10	3
0	0	0	0	3	12	16	37	11	0	5	9	12	12	2	2
0	0	0	0	5	20	27	7	12	5	15	39	13	36	12	0
0	0	0	0	0	8	12	42	21	9	51	9	15	64	14	0
0	0	0	0	0	6	29	24	80	13	13	9	13	24	2	1
0	0	0	0	0	4	9	27	42	31	10	29	20	7	0	0
0	0	0	0	0	4	7	31	9	25	9	19	18	16	3	0
0	0	0	0	0	0	1	8	5	16	3	3	3	1	0	0
0	0	0	0	0	0	0	1	3	0	0	1	0	0	0	0

Figure 10 – A matrix showing pressure values of the map in figure 9

Figure 11, 12, and 13 depict examples of how the new algorithm will work when a person sitting on the mattress is using the app.

Figure 11 – A person sitting in a chair

Figure 12. The pressure map showed a shift in pressure from lower area to the upper one when the user leans forward.

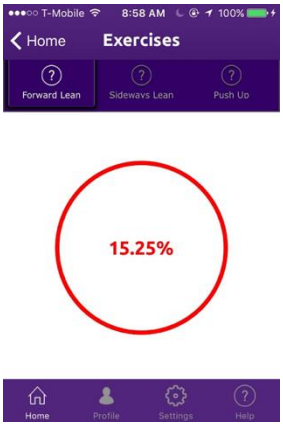

Figure 13 – The app verified that there is a shift in pressure when the patient is doing forward lean exercise

The algorithm of the second phase of the app is shown in figure 14.

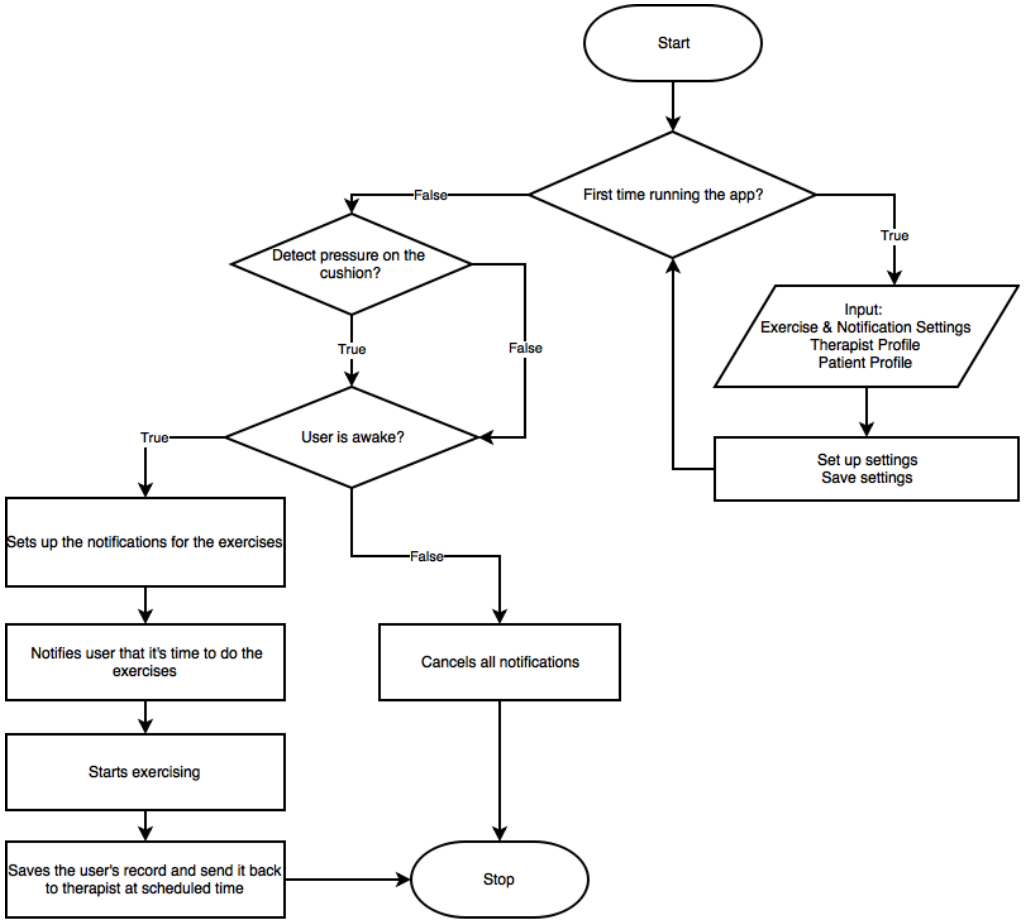

Figure 14 – Algorithm of the app in phase 2

It is important to realize that the app was still unable to make an efficient exercising schedule for the patient. For the purpose of improving the user experience, the patient will have to press a button to notify the app for being awake or asleep. In the figure shown below, the patient will have to press the third button to enable the app's scheduling feature.

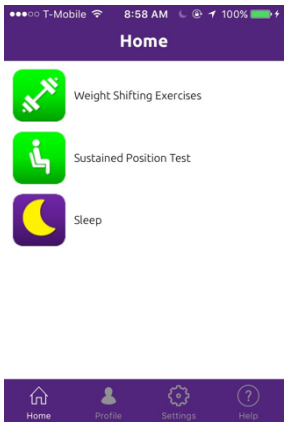

Figure 15 – Main interface of the app

3. Conclusions

After finishing phase 1 of the project, the app was tested by several patients and received positive results from them. However, some issues were also identified after phase 1. These issues were: 1) the lack of reliable technology to verify the patient's participation; 2) the inability of the app to effectively set up the schedule and firing notifications. In phase 2, a further upgrade of the app will be started in Summer 2016. For the purpose of improving the user experience, a pressure mapping mattress will replace the current technology used by the app – the accelerometer. This new approach promises a more reliable way to verify the hypotheses stated before. Phase 3 of the project will include volunteer wheelchair-bound patients who are going to use the app and the data collected will be given to the clinicians for further research. This data will be used as the evidence-based practice of weight shifting exercise to prevent pressure ulcers.

4. Acknowledgments

The author wishes to express his appreciation to:

- Faculty advisor Dr. Arshia Khan for the support and precious advice.
- Swenson College of Science and Engineering (SCSE) Undergraduate Research Program coordinator Penny Morton for the opportunity given.
- Department of Computer Science at the University of Minnesota Duluth for providing all of the equipment needed.
- Syed Salik Hafeez, a graduate student from the Department of Electrical Engineering for helping with the pressure mapping mattress.

5. References

1. Mayo Clinic, "Bedsores (pressure sores)", MayoClinic.org, http://www.mayoclinic.org/diseases-conditions/bedsores/basics/definition/con-20030848.

2. Sonenblum, Sharon E. et al, "Effects of Wheelchair Cushions and Pressure Relief Maneuvers on Ischial Interface Pressure and Blood Flow in People With Spinal Cord Injury", Archives of Physical Medicine and Rehabilitation, Volume 95, Issue 7, 1350 – 1357, http://www.archives-pmr.org/article/S0003-9993(14)00034-3/abstract.

3. Cooper KL. "Evidence-based prevention of pressure ulcers in the intensive care unit". Critical-Care Nurses. 2013;33(6):57–66. doi: 10.4037/ccn2013985, http://www.aacn.org/wd/cetests/media/c1363.pdf.

4. National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel, Pan Pacific Pressure Injury Alliance. "Prevention and treatment of pressure ulcers: clinical practice guideline". Haesler E, editor. Perth: Cambridge Media; 2014.

5. TechTarget, "Accelerometer", WhatIs.com, http://whatis.techtarget.com/definition/accelerometer.

6. TechoPedia, "Accelerometer", TechoPedia.com, https://www.techopedia.com/definition/24430/accelerometer.