Towards mHealth Solutions for Asthma Patients

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TOWARDS mHEALTH SOLUTIONS FOR ASTHMA PATIENTS

by

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ABSTRACT

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With the recent, rapid growth in mobile-computing technology, mobile health (mHealth) is becoming a popular research topic. mHealth is one of several examples of how using technology in the health sector is being more advanced every day. mHealth is being applied to the care of a broad spectrum of diseases from acute to chronic, such as the flu, asthma, and cancer. Due to the easy-to-understand and friendly user interfaces, mobility and cost effectiveness; a mobile application can be a powerful tool to collect patient information. Asthma is a common disease around the globe. Collecting the proper symptom, trigger, peak-flow and inhaler-consumption information is crucial for assessing the patient's severity of disease and tailoring treatment for people who suffer from asthma. Collecting and preserving this information on daily basis can help doctors provide a better treatment plan. Also, this information gives the patient an indication about if he/she needs immediate treatment. Collecting this information by using a traditional medium, such as pen and paper often results in lost data or inability to make the date interoperable with the health providers. A mobile application can address these issues as most people carry smartphones. This thesis works towards a solution for a patient centered asthma data collection tool using mHealth. The necessity of a mobile application for asthma patients' data collection is analyzed in the thesis. Application features, scopes and data representation methods are determined by talking with experts. A state-of-the-art mobile app is designed and implemented. The features of this application are evaluated. The application is capable of serving all the important aspects of data collection for an asthma patient. Finally, the future improvements are analyzed along with the conclusion.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

mHealth	Mobile Based Healthcare
SMS	Short Message Service
HEPA	High-efficiency particulate arresting
PT	Physical Therapist
peakFlow	Measurement of the air flow of Asthma Patient
Symptoms	Asthma symptoms.
Trigger	Asthma triggering elements.

CHAPTER 1: INTRODUCTION

Due to the many advantages of using mobile phones for patient data collection, mobile health (mHealth) is a growing research area [1]. Patients' data collection is an important factor to provide more accurate treatment for the patient. Collecting the data using traditional methods such as, a pen and paper, often fail to collect the data need by health providers to tailor asthma treatments. For instance, paper is often lost or not available when a patient is away from home. Furthermore, paper is not an easy method of transferring data to a health provider's office from a patient home [1]. Therefore, an easier data-collection medium is needed so that the patient can enter the necessary information in a convenient way. This information can be used by the doctor to determine the patient's current asthma status. In order to build this data-collection tool, it is important to understand what information should be collected first.

Smartphones are commonly used and are very much available. In USA, 90% people are using cellphone and 64% of them are using a smartphone [2]. There are many known advantages for smart mobile phones, such as user-friendly data entry, portability, being relatively inexpensive, etc. Among the different types of smartphones, the iPhone is currently one of the best smartphone systems that allows for adaptation and flexibility at each level of its operating system [3]. The iPhone can easily be used by patients due to its user-friendly interface and data-entry capability [1]. The iPhone device is not overly intrusive and is enjoyable to use. As a data-collection tool, the iPhone can be used to monitor the patient's condition, and treatment can be given accordingly. The touch-screen support allows for easy user interaction as well as making it possible to enter data by just using a fingertip. This feature is very helpful for patients who are suffering from

asthma. The touch feature facilitates less effort than using a mouse or keyboard. The wireless communication allows the data to be stored and shared remotely. Thus, an iPhone app can be really helpful for patients' data collection.

As with many other diseases, data collection is important for asthma patients. In some aspects, data collection may be considered even more important for an asthma patient than for a patient with other diseases [6]. Due to the chronic nature of asthma, regular monitoring and data collection are required. The asthma patient's treatment plan is highly correlated with his/her condition, and data collection is the most effective way to determine the patient's condition (current disease status). Furthermore, treatment is based on nationally accepted guidelines which take into account the type and timing of patient symptoms [4]. In order to apply these guidelines correctly, accurate patient reported data is required. Also, it is important to determine which data should be collected for the patient. The above mentioned guidelines also help with determining what data to collect. As we have discussed, a mobile device, especially an iPhone, can be a very good medium for gathering the patient information. We have decided to perform research to develop a data-collection application on the iPhone platform that can be used by the asthma patient; then, the information can be shared with the doctor in a presentable and understandable way.

The goal of the thesis was to apply a user-centered design to the development of this mHealth application to collect patient collected asthma data [5]. By applying this method, the application attempts to make the asthma patient's data entry as easy as possible. We tried to identify the scope of the useful information that is necessary. Once the data-entry scope was defined, we performed research using expert opinion and user

input on how the specific type of data entry can be made easier for the patient. Based on our research and analysis, we finalized the user interface. We designed a mobile database for the application. We also performed research on the requirement analysis. The research was about how the data should be presented. The desired outcome of the application was to help the doctors use patient reported data effectively when to create personalized treatment plans.

This thesis contains seven chapters. The Introduction chapter highlighted the necessity of a mobile application for data collection and also provided a summary of the thesis work. Chapter 2 describes the Background for mobile health, how a mobile phone or smartphone is used in different areas, and how effective it is. Chapter 3 provides the Motivation behind the thesis and the development of the iPhone application for asthma patients' data collection. Chapter 4 gives an overview of the previous work done in similar areas. A comparison is made between the existing approaches and the features provided by our application. Chapter 5 describes the technical details about how the application is designed and developed. The application's features are also described in this chapter. The back-end database design is presented in Chapter 5, too. The step-by-step user manual for the application is also given in Chapter 5. In Chapter 6, we evaluate the application by giving some examples about how the different features of this application can provide benefits in real-life scenarios. Chapter 7 provides a Conclusion where the thesis, the application and the evaluation are summarized. Future improvement for the application is also described.

CHAPTER 2: BACKGROUND

2.1 MOBILE HEALTH

When mobile devices, tablets and computers are used for health services, it is called mobile health [7]. Additionally, this includes the applications that use mobile devices for collecting community and clinical health data; delivering healthcare information to practitioners, researchers and patients; real-time monitoring of patients' vital signs and providing care directly.

In recent years, this field has largely emerged for developing countries [8]. The availability of mobile devices and the growth of health-related apps are playing an important role in the growth of mHealth. Currently, more than 20,000 health-related apps are available for mobile devices, whereas in 2010, the number of apps was about 4,000. Through the industry report, it is estimated that almost half a billion people will be using mobile health by 2015 [9].

Mobile health has significant advantages:

- mHealth is necessary when you're on the move, whether it is for a physician, a clinician or a patient.
- It is possible to improve a patient's health condition faster because the physicians can keep track of their patients, improving the quality of healthcare.
- mHealth is cost effective.
- mHealth assists with the social-network availability for doctors to reach out and connect with people in different locations.

Although mobile health is really helpful, there are several barriers exist. There is barrier of difficulties with interoperability between different IT systems. Another possible barrier is inability of providers to bill/charge for the service. Most crucial barrier is security risks and privacy threats to telehealth and mobile apps, such as

- During the collection or transmission, it threatens the privacy of telehealth, which includes a breach of confidentiality.
- Because the health apps are mainly used on portable devices, such as smartphones and tablets, which can easily be stolen, the data collected by the apps are particularly at risk.
- With mHealth, patients and providers may rely on consent forms, which is the result of weak privacy protections. Because it is possible for the mobile app makers and the device manufacturers to share patient information with third-party advertisers, patients are at risk for having their information stolen.

Because data-collection platforms have moved to an online template, a web app is a classic solution. Normally, the traditional portable systems (laptops or tablets) are difficult for a patient to use because of their large size, awkward interfaces and limited battery life. Also, the cost of those devices is quite expensive. Therefore, in this case, smart mobile-phone technology and tablets are used for collecting data and is more suitable for a high-tech hospital environment. Only a small number of hospitals have switched to the use of mobile systems (and applications) [10]. Using these systems, it would be possible to increase the efficiency and to reduce errors for a multitude of applications. Currently, iPhone web applications are able to combine the power of internet-based solutions with the simplicity of multi-touch and gesture technology. These

applications help to create more efficient workflows that can integrate the patient directly within a hospital or clinical setting.

2.2 CASE STUDY

Several researchers studied mobile data collection for patients. Consequently, some of the patient data collections mobile application which have been done by others are discussed here. A secure and customizable tool named Poimapper [11] has been utilized to collect general health data and for flexible patient monitoring in field situations. With this tool, mobile health data can easily be transferred to central health records. This solution can be extended to support on-device risk assessments. The tool is really helpful for mobile health workers in rural areas. Poimapper is a solution that helps to accomplish national rural-health missions.

Based on patient-specific health data, SMS alerts and reminders are automatically sent to patients by Poimapper. Secure, embedded messaging is possible between field workers and health-center experts. Similar to OpenMRS [12], Poimapper can integrate existing medical records into the system. Likewise, Poimapper can also give fully configurable support for a patient's existing data structure. Therefore, Poimapper is a perfect mobile-health solution for community health workers; the tool is used for tuberculosis, HIV, cancer and anemia monitoring as well as treatment across Africa and Asia [11]. The more detail description on these mobile health applications is given on chapter 4.

CHAPTER 3: MOTIVATION

Current National treatment guidelines suggest a series of paradigms to determine whether asthma is controlled [4]. If the physicians are using those paradigms to assess treatment needs and how effective such evaluations are compared with the patients' evaluation of asthma control are still unknown. Some Canadian asthma consensus guidelines are available. This guideline is used by both physicians and asthma patients to determine whether the asthma control is acceptable [13].

3.1 A CASE STUDY

In this study, about 183 Canadian physicians analyzed 856 patients who had mild to slightly uncontrolled asthma and who were not using anti-inflammatory medication when they began the study. Two questionnaires were completed by the physicians; the patients' level of asthma control was estimated on an ordinal scale from 1 (very poor) to 5 (very good), and the second questionnaire indicated the frameworks that were used to analyze this level of control. The patients also answered an asthma-control questionnaire that was identical to the one completed by physicians. In this case, a 6-question, asthma-control survey was completed, where each question had values on a 7-point (0-6) scale.

This study [13] shows that about 66.2% of the patients and 43.3% of the physicians graded the control of asthma symptoms as very good. The patient and physician-rated average scores for asthma control were 3.0 0.2 and 2.6 0.2. On the Juniper asthma questionnaire, the average patient score for the asthma questionnaire was 12.2 6.3. Here, the physicians used seven parameters to assess the patient's level of

asthma control including coughing, wheezing, shortness of breath and limiting physical activities. As an evaluation parameter, pediatricians used coughing more frequently, and the respirologists measured the pulmonary function more than physicians [13].

This study specifies that selecting asthma-control criteria does not always match the current asthma guidelines, and also, asthma-control criteria vary among physicians. Sometimes, both the patients and physicians consider the asthma to be controlled while, according to the current guidelines, it is actually not controlled. This study highlights the need for updated communication–to both patients and physicians–about current suggestions for how asthma control should be determined.

3.2 SCENARIOS

In order to realize the importance of a mobile app for asthma patients' data collection, we can look at different scenarios.

3.2.1 FIRST SCENARIO

An asthma patient may have one or more symptoms. Among these symptoms, a shortness of breath is the most common issue. It is important to know an asthma patient's number of occurrences for shortness of breath. The patient's condition varies directly with the frequency for having a shortness of breath. Following are the discussion on how collecting information about this symptom (shortness of breath) can play a vital role with an asthma patient's treatment plan.

Let's assume that there is an asthma patient named "X." One day, he had a shortness of breath, but for the next 10 to 15 days, he does not have any breath problems. Then, he experienced a breath problem for a few moments. This situation means that his

asthma problem is controllable and that it is not necessary to change his treatment plan. On the other hand, another asthma patient named “Y” is feeling breath problems very frequently, such as almost every day or every one to two days. Therefore, it is necessary to change her treatment plan immediately.

Thus, by analyzing the frequency of the symptoms’ occurrence, it is possible to determine if treatment is necessary or if a change in the treatment plan is needed. This information also helps to give appropriate treatment to an asthma patient as he/she has received before. This situation is not only applicable for a shortness of breath, but there are also many other common symptoms for asthma, such as coughing (especially at night), wheezing, affecting speech, sleep problems, etc.

By analyzing of any of the asthma patient’s symptoms in such way, it is easier to give a better treatment. For this analysis, the patient needs to obtain a reading for these symptoms from time to time, a large hassle for the patient. As a result, a mobile app can be very helpful in this case so that a patient can record the occurrence of any symptom within a few minutes just by clicking a button on his/her mobile phone; the information will be saved, and a nice report can be prepared. This report/graph can help the doctor to make an effective decision about the patient’s treatment plan.

3.2.1 SECOND SCENARIO

Every patient with asthma has different triggers that can cause an asthma attack. Controlling the environment by reducing or stopping the patient’s triggers is an important part of treatment. Thus, it is important to know the type of triggers that can increase the asthma severity for each patient. For example, some patients have a dust allergy; some people have a smoke allergy; and others have an animal-dander allergy. These allergies

can create asthma symptoms. An asthma patient should consult with his/her physician about his/her triggers so that he/she can prevent his/her asthma attacks. We can briefly explain the necessity of information collection for these triggers with a couple scenarios. Let us assume that a person named X has asthma and that he has an animal allergy. Normally, animal dander comes from the skin, hair or feathers of warm-blooded pets, including dogs, cats and birds. Therefore, it is recommended that X should not have a pet. If he must have a pet, the animal should never be allowed in his bedroom. He should wash his pet weekly. If he has forced-air heating, he should filter or seal the air ducts that go to the bedroom. He should also avoid products made with feathers (such as pillows). He should use a vacuum fitted with a HEPA filter.

On the other hand, patient Y has a dust allergy. Usually, dust mites are microscopic insects that are found in the home. Because Y has dust allergy, she should put her mattress and pillows in airtight covers; she should clean all bed linens, clothing, and stuffed toys weekly in hot water in order to kill dust mites. For this task, the water temperature should be 130 F. She must use an air conditioner or dehumidifier which may decrease the number of dust mites.

In order to get proper directions about minimizing the triggers' effects, each patient must write which triggers are affecting him/her more and how frequently. The patient needs to write down the information from time to time so that his/her physician can suggest proper directions and can help him/her to eliminate trigger problems. A mobile app can be very helpful so that a patient can take a reading for any occurrence of a trigger within a few minutes by clicking a button on his/her mobile phone; the

information is saved, and a nice report can be prepared. This report/graph can help the doctor to make effective decisions about the patient's treatment plan.

3.2.1 THIRD SCENARIO

A peak-flow meter is a device that can measure how well air moves from a person's lungs, and the peak-flow rate can be used to determine if there is narrowing in the airways. A serious attack may be avoided by taking medicine before the symptoms occur. The device is really helpful for asthma patients; it is recommended that all patients, age 5 and older, who have severe asthma should use a peak-flow meter. For asthma treatment, the patients' regular peak-flow number is necessary, and the peak-flow zone is determined for each patient to prescribe the proper treatment. The peak-flow zones are based on the traffic-light concept: red means danger; yellow means caution; and green means safe. These three zones are different for each patient, and the doctor helps determine the peak-flow zones. Based on the peak-flow reading, doctors can determine the patients' actual situation and can change the treatment plan if necessary. For this purpose, patients need to collect a peak-flow reading regularly and also need to record the time. In this case, a mobile app can be very helpful for asthma patients. By using a mobile app, the patient can easily collect his/her regular peak-flow number, including the time and date. Based on the peak-flow reading, the doctor can immediately change the patient's treatment plan and can also provide better treatment than the patient had previously.

From the case study and the scenarios, it is obvious that, a mobile application can play a vital role in improving the asthma patient's treatment plan.

CHAPTER 4: RELATED WORK

There is a significant amount of research work, and mHealth-based application development has been done recently. The number of health related iPhone applications is more 700 [14]. Among this large number of applications, some of them are specific to the data-collection scenario. These applications have features such as self-report and sharing information with the consulting physician. A significant number of medical professionals are now using mobile devices to access patient information, treatment history, laboratory test results, medication information, symptoms, etc. [15]. Among these applications, there are a large number [16] that are specially designed and developed for asthma patients. There are some other health-related applications that have been developed for patient-information collection and management. The general-purpose application is briefly discussed followed by a detail discussion on existing asthma data collection.

4.1 HEALTH-RELATED MOBILE APPLICATION

Among the various health-related mobile-phone-based applications, fitnessBuilder, pioneered by PumpOne, is a physical-therapy information system that allows a physical therapist and the client to communicate. This application has some nice features, including the therapist assigning exercises and the patients reporting on the progress. The progress data can be monitored by the physical therapist (PT) [17]. There is another mobile-phone application named the Airstrip OB application; it is used for monitoring labor with delivery-room data [18]. The Hopkins Antibiotic Guide application is used for managing and diagnosing diseases, and it lists pathogens with a reference guide for antibiotics [14]. Apart from the data collection, the mobile application is also

used for reference information. There is a significant amount of pre-collected health-related information stored in the database, and this information is accessible by using a simple mobile application. An example of such a drug-information application is Epocrates which is utilized by 100,000 physicians using their iPhones [19-20]. Other drug-database applications include Medilyzer and Procedures Consult. Typically, the reference applications are very user friendly, containing images, animations and videos [21].

Besides the data collection and the reference application, there are other health-related applications that help with the decision-making process. These applications assist with making decisions about a treatment plan; examples of such applications are KidneyCalc as well as the Handbook of Signs and Symptoms [21]. There are Frequently Asked Question (FAQ) mobile applications such as MedMath and MedCalc [14]. Other mobile-based health applications include the clinical workflow-process management system; B. Health is one such project.

4.2 ASTHMA-RELATED MOBILE APPLICATION

Research [22] has demonstrated that self-managing asthma may enhance the user's asthma outcomes, and an internet based tool has been suggested by the research to observe and self-manage asthma. At the same time, a recent study has shown some disadvantages with using a web interface, causing people to stop using web applications after a short time period [23].

4.2.1 SMS-BASED MOBILE-APPLICATION SOLUTION

A short description of a study is given here, where the primary objective was to analyze, from a user's perspective, the workability of using a short message service (SMS) for asthma-diary data collection with mobile phones; the secondary objective was to explore patient compliance with an SMS diary, which was measured by response rates over time. For this data-collection study [24], 12 patients with asthma (6 females, 6 males) participated; their median age was 38.5 (range: 13-57) years. The average feedback rate per patient was 0.69 (range: 0.03-0.98); that is, half of the participants noted more than about two-thirds of the desired diary data. Moreover, feedback rates were comparatively constant during the study period with no signs of decreasing usage over time. Based on the SMS collection, this study showed a significant response rate for the data. In this study, patients received 4 SMS messages every day: a medication indication, a request to enter the peak flow, a prompt for data on sleep loss, and medication dosage. Those inputs were collected in a database for each patient. That process was continued for 2 months for each patient. Finally, a group interview was arranged to ask attendants about their disease, to observe their attitudes and to share their experiences with the SMS asthma diary heir future expectations.

The result of this group interview showed that the attendants were passionate about the SMS. This process became an integrated part of their everyday life. However, the participants wanted a simpler application with only one SMS message to answer. They also demanded a system with a customization web interface for the data entry. The unification of SMS data collection and a historic web page for the data display and system customization may be a better and more employable tool for patients than using

web-based asthma diaries which suffer from high erosion rates. Because mobile phones are part of people's everyday lives and can enable dynamic requests for data wherever the patient is, SMS collection of asthma diary data is workable. This becomes part of the participants' disease management, and this process also gives them a sense of control over the disease, providing more flexibility. At the same time, the tool helps the participants to reach their goals, so it can easily be an appropriate tool for supporting the self-management of asthma. Thus, a better approach is required to make the methods suitable with defined calculation and different facts.

Besides the SMS-based application, there are some other asthma patient-information mobile applications. The following sections have a comparative analysis for the different approaches, covering the features used by other researchers. The features are also compared with our application's attributes.

4.2.2 ASTHMAMD

AsthmaMD is a self-management application with features such as a diary, graphing ability and medication logs. This application encourages the physician and patient's interaction by sharing charts and information as well as sharing the user's information for research purposes [21].

The mentionable features of this application are logging in on the go, chart severity, sending information to the physician, and customizing medications and the action plan.

4.2.3 BREATHE

Breathe is a mobile, asthma self-management application for consumers. Being one of the most common chronic diseases, self-management is a key element for controlling asthma. Self-management can be achieved by collecting the patient's asthma health information, and this goal is the primary aim for developing the Breathe application. A set of web-based mobile asthma tools have been developed to empower patients to manage the disease on a daily basis [21]. This application is helpful with increasing adherence to the recommended self-care practices, improving self-efficacy and enhancing the overall patient experience [21]. This application's development is sponsored by the Ontario Lung Association as a part of the Canada Health Info Way Consumer Health Solutions Program.

Breathe includes features such as regular symptom-information collection, access to a patient's asthma treatment plan, medication information, a nice and user-friendly visualization of the user's data for the doctor's review, and alerting functions to warn the users if needed.

4.2.4 MOBILE APPLICATION BY AMERICAN SOCIETY OF CLINICAL ONCOLOGY (ASCO)

The American Society of Clinical Oncology (ASCO) developed a free iPhone and iPad application [25], Cancer.net Mobile, for cancer and asthma patients. This mobile application provides information and tips using videos, podcasts and up-to-date information.

The application has other features, such as enabling a patient to ask questions and the answers can have provided in voice form, in terms of the medications, and symptoms. The medication information can be stored with details, including the prescribing provider. The symptoms, along with the severity and a time stamp, can be stored. The application also facilitates downloading articles, literature, news and videos.

The different features of the various approaches are summarized in Table 4.1. The features supported by our app are also given.

Feature	AsthmaMD	Breathe	ASCO App	Our Application
PeakFlow	Yes	No	No	Yes
Triggers	Yes	Yes	No	Yes
Medicine	Yes	Yes	Yes	Yes
Symptom	Yes	Yes	Yes	Yes
Inhaler	No	No	No	Yes
Report	Yes	Yes	Yes	Yes
Share with Doctor	Yes	No	No	Yes

Table 4.1. Feature availability comparison with other application

CHAPTER 5: OUR APPROACH FOR DEVELOPMENT

5.1 FUNCTIONALITY OF THE APPLICATION

An entire smartphone-application asthma-monitoring system was developed with a combination of screens and a complete navigation system among those screens. The application interface is made versatile so that we can maximize the user's satisfaction or willingness to use the application every day. Some major design considerations to make the application are listed here.

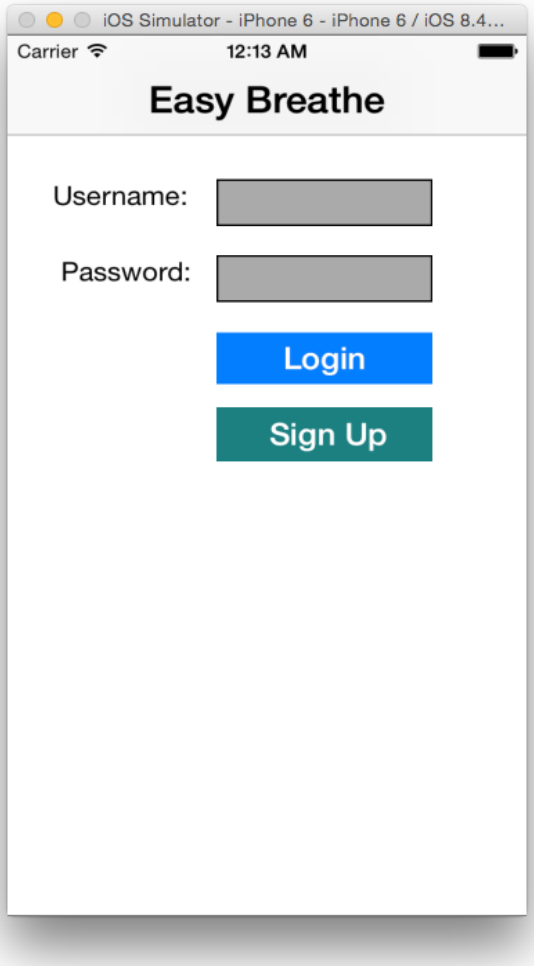

Figure 5.1.1: User login page

The first screen is designed as a single point of operation for application users. “Login” and “Sign Up” buttons as well as two text boxes are provided. Users will press the “Sign Up” button first. Then, they will go to the next screen to create an account. Only when a user has an account will he/she enter a username and password in the text box and press the “Login” button. During the user’s first experience with the app, he/she will not be able to press the “Login” button. After pressing the “Sign Up” button, the User Information page will appear, and the user will give all of his/her information in the textboxes as input, pressing the “Next step” button to advance to the next screen.

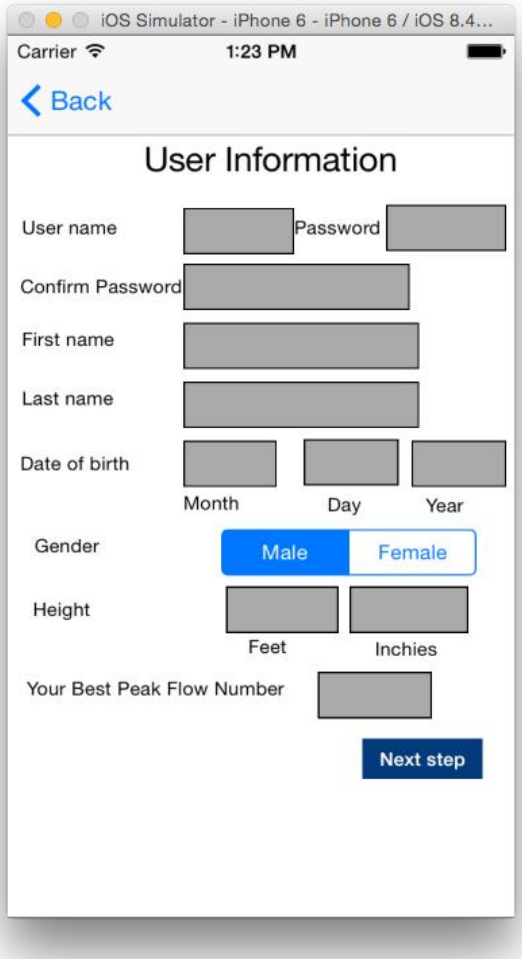

Figure 5.1.2: User information page

After giving all the necessary information, it will be saved in the backend database, which is connected with the server, when the user presses the Next step button. Now, the user can see the medicine page where lots of medications, which are normally used for asthma patients' long-term treatment, are listed. The user will be able to select the medicine which he/she is utilizing long term from that list.

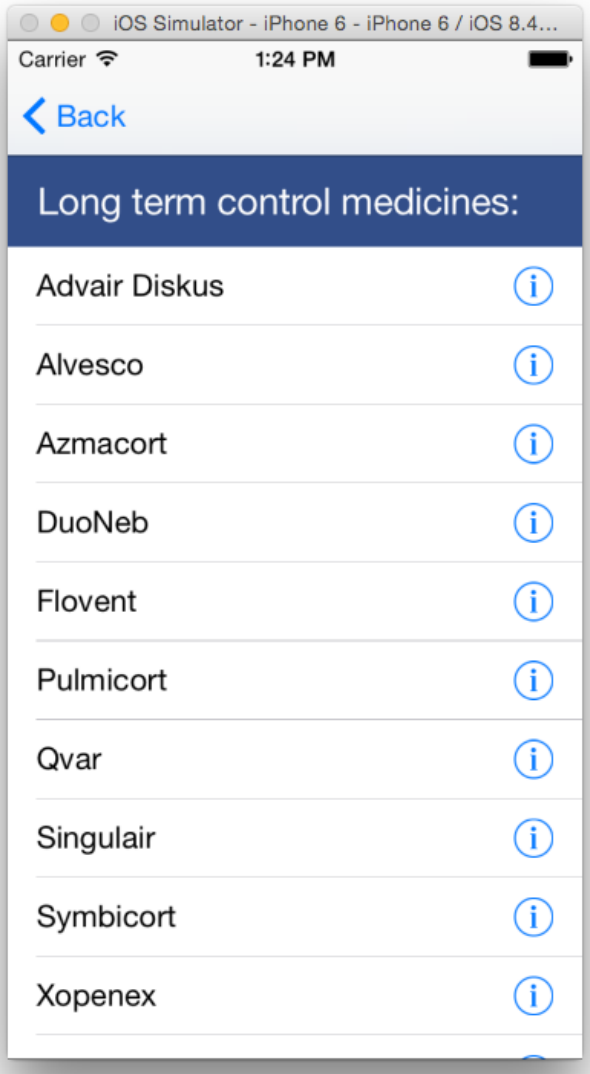

Figure 5.1.3: Medicine information page

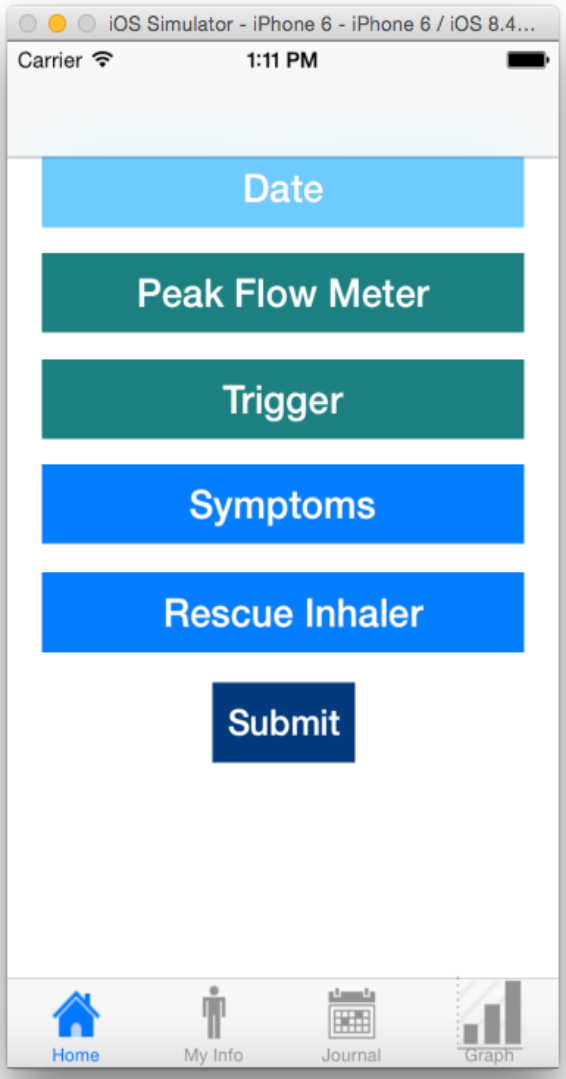

Figure 5.1.4: Home screen

When the user selects a medicine, one more screen will appear where he/she gives the dose and also the frequency per day. Then, the user will be back at the medicine page. If the person uses different types of medicine which are not listed on the medicine page, then he/she will be able to add the name to the medicine list by using the "Add More" button. Additionally, users have to press the "Next step" button, and all the medicine

information will be saved in the back-end database. Moreover, the user will see the most important information which may have provided earlier. After pressing the "Finish" button, the account will be created, and the user will receive a confirmation with a pop-up message. Then, the first screen will reappear where the user can log in to his/her account and will be able to enter the application's Home page. On the home page, six buttons and four tab-bar buttons are available; by using those buttons, the user will be able to use the application properly.

Among the four tab-bar buttons, one is named "My info." If the user thinks that he/she gave some incorrect information about his/her medicine or his/her personal data, then he/she can press this button and get a new screen. On that screen, he/she will have options to change the personal and medicine information. Next, the user has to press the "Update" button to save his/her updated information in the database.

By pressing the "Date" button, users will see a calendar where he/she can select the time and date when he/she enters the application.

When the user presses the "Peak Flow Meter" button, he/she will be able to see a video about using a peak-flow meter. He/she will also give his/her current peak-flow number.

Another button is "Rescue Inhaler." By pressing that button, the user will select whether he/she is using an inhaler. If yes, then he/she has to put the number of puffs taken every day.

There is also a "Symptoms" button. By utilizing this button, the users will enter another screen where several asthma symptoms, such as cough, wheeze, speech-affected,

etc., with example pictures are available. Now, the user will select which symptom he/she has and what type of difficulties he/she has to face regularly.

Figure 5.1.5: How to use a Peak Flow Meter

Another one is the “trigger” button, and by pressing that button, the user will be able to enter a new screen where three different types of triggers, outdoor trigger, indoor trigger and other trigger, are available. We kept the three types of triggers as three buttons. When a user selects a button, he/she will be able to enter the details for that type of trigger and can also select his/her allergy items.

After finishing entering necessary information, the users have to press the "Submit" button from the Home screen so that all the information can be saved in the database. Remember, without pressing the "Submit" button, information will not be saved in the database. Users can change their selected items any time before pressing the "Submit," button but after pressing the "Submit," button changes will not possible.

5.2 GRAPHS PRESENTED IN THE APPLICATION

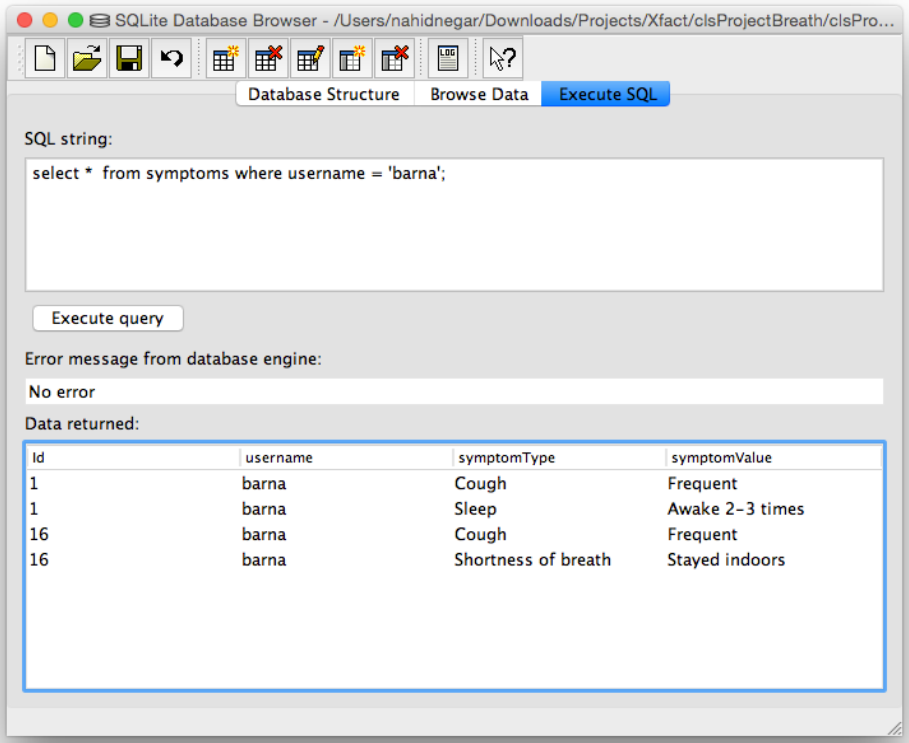

Figure 5.2.1: Data entry for symptoms

To show the graph based on user input, one tab-bar button, "Graph," is used for this application. For symptoms, we used one biograph. All the symptoms that a user selected at different times are shown using various colors. From this graph, it will be

clear which symptoms the user has more frequently. Therefore, this user has an allergy that causes that symptom, and it will be easier for a doctor to give the patient proper treatment. To show this biograph, first the number of symptoms is counted for each user by querying the “symptoms” table in the database. Then, each symptom’s percentage ratio is calculated for that user. Finally, we used different colors for various symptoms and placed those on that biograph.

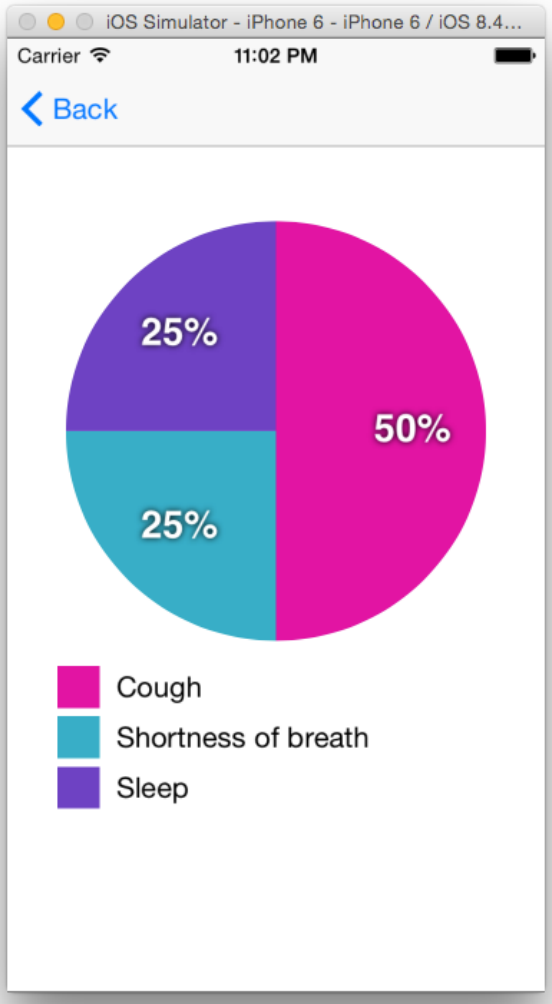

Figure 5.2.2: Pie chart for the user’s symptoms

For example, here we show two screen shots for a user. The first one (Figure 5.2.1) is the user's selected symptoms from the database's "symptoms" table. If can be found that the user only selected two symptoms: cough and sleep affected. The second one (Figure 5.2.2) is a pie chart which is based on the user's selected symptoms, cough and sleep affected. Different colors are used in this chart for cough and sleep problems in the pie chart which is shown in the second screenshot (Figure 5.2.2).

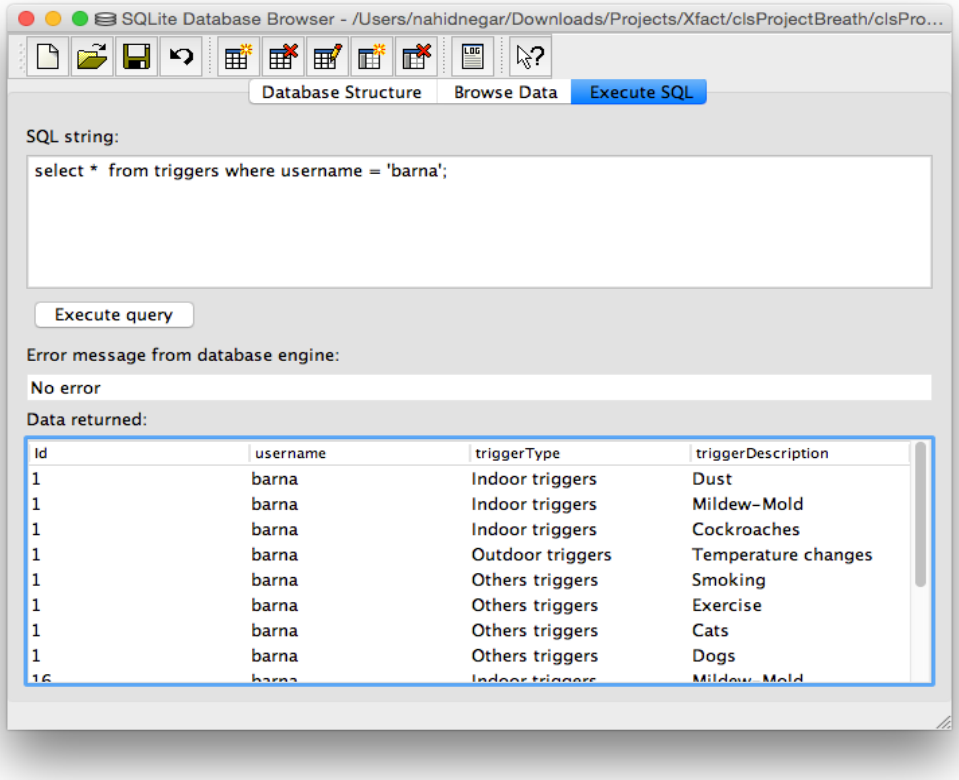

Figure 5.2.3: Data entry for the triggers

Another biograph is used for representing the triggers. In this biograph, all the user's triggers, which he/she selected at different times, are shown using different colors as was done with the symptom graph. From this graph, it is clear which triggers affect the

user more. Therefore, this user has identifiable allergies which are very helpful for the doctor to treat the patient. To show this biograph, the number of triggers are counted for each user by utilizing a query of the database's "triggers" table. Then, the user's percentage ratio is calculated for each trigger as well as the symptoms. Finally, different colors are used on the graph for various triggers.

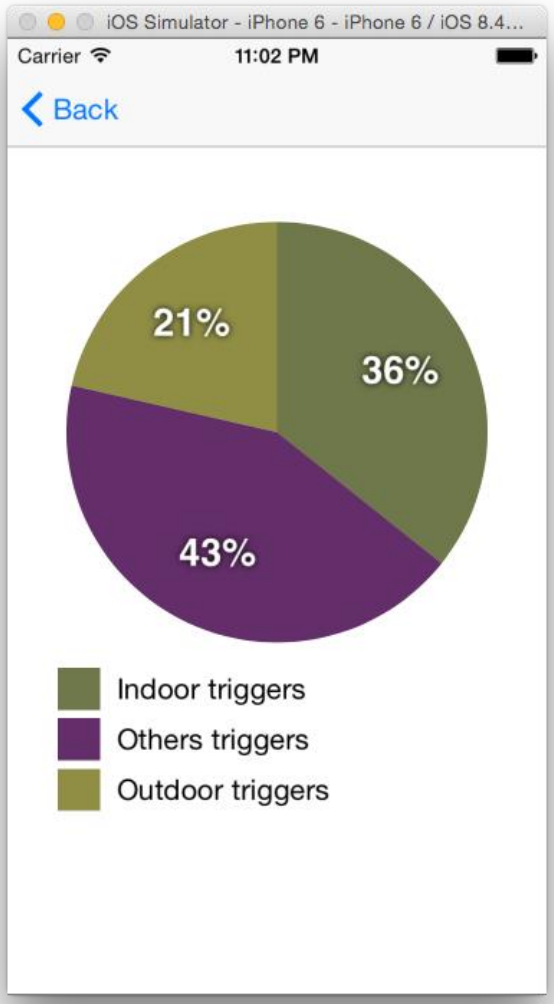

Figure 5.2.4: Pie chart for the triggers

Here is an example with two screen shots for a user. The first one shows how a user selects triggers from the database's "triggers" table. We can see that the user selected three trigger types: most triggers were from the Others triggers category; fewer issues were from the Indoor triggers category; and the smallest number was from Outdoor triggers. The second one is a pie chart which is created based on the user's selected triggers, and we used three different colors in the pie chart for the three trigger types as shown in the second screenshot.

A bar graph is shown (Figure 5.2.5) based on the user's peak-flow number and the number of inhaler puffs which he/she gave as input at different times. Before giving the description for this graph, we need to explain what the peak-flow number is as well as how to measure the peak-flow number, which is necessary for asthma patients. The peak-flow rate is the maximum flow rate generated during a forceful exhalation, starting from full lung inflation. The peak-flow rate primarily reflects large airway flow, and the rate depends on the patient's voluntary effort and muscular strength. The peak-flow rates can show if the asthma is getting worse, even before a person feels any symptoms. In addition, measurements with a peak-flow meter can help the healthcare provider make decisions about the patient's treatment and adjust medicines as necessary.

A peak-flow meter can be used as a signal when asthma is getting worse. Asthma sometimes changes gradually. The peak flow may change before the patient feels a change. Peak-flow readings can show when to start following the steps of the asthma action plan that were developed with the healthcare provider. The peak flow can help determine the episode's severity, when to use rescue medicine and when to seek emergency care.

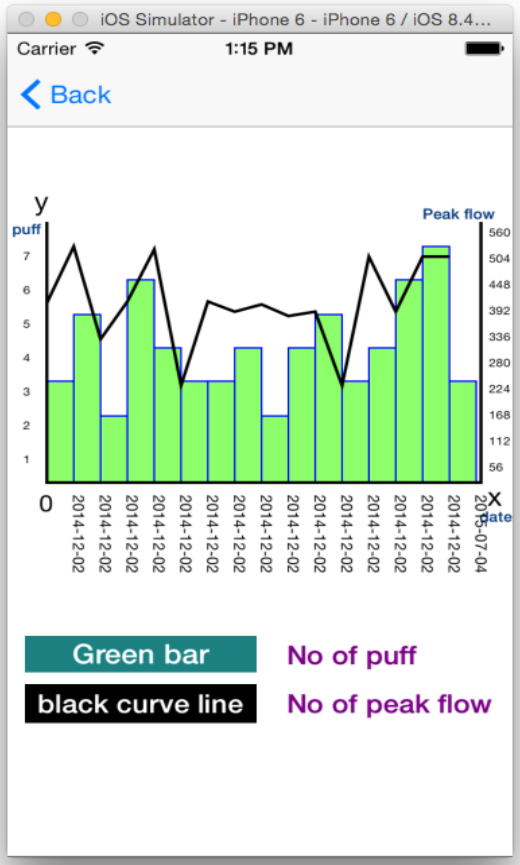

Figure 5.2.5: Bar graph for the date vs peak flow number and no. of puff

In this graph, the X-axis represents the date/time. In the Y-axis, the number of puffs along with the peak-flow numbers are presented. These numbers are given by the user as input at different times. First, a date array is used. Then, all the different dates/times for a user is read (the different times that the user gives input) from the database. Here, the query is created by joining the “peakFlow” and “Inhaler” tables to get the date values. Then, all the date values are kept in the date array and put it on the X-axis of the graph.

Similar to the date array, another array named peakFlowArray is used for keeping all the user's peak-flow numbers for different times. Here, all the user's peak-flow numbers are collected from the database by using a query on the "peakFlow" table. Then, all the values are kept in the peakFlowArray and put it on the graph's Y-axis. In this graph, the maximum value of the peak-flow number is kept 560. Here, the Y-axis starts at 310 and ends at 130 (the iPhone has opposite Y-Coordinate numbering, from high to low). Therefore, the total length of the Y-axis is calculated as the difference of the starting point and the ending point. Then, the total length is divided by a value which is slightly bigger than the maximum peak-flow number, and this calculated value is used for drawing the step of the Y-axis. The value is chosen to be a little bigger than the maximum peak-flow so that, the maximum point doesn't touch the top of the graph, which may not look good.

The X-axis starts at 25 and ends at 300. Each step of the X-axis is calculated by finding the difference between the starting point and the ending point; that value is then divided by the array_count. Here, the array_count contains the total number of unique entries. The number of dates is calculated from the date when a reading is started until the last date when a reading is taken; the peak-flow number is shown with a green bar.

Similarly, another array puffArray is used for keeping all the user's puff numbers which he/she gave as input at various times. One query is prepared using the database's "Inhaler" table to collect the number of puffs. Then, in the same way, the number of puff values are kept in the puffArray and put them, one by one, on the graph's Y-axis. In this case, the maximum puff value is kept as 7. Here, the Y-axis starts at 310 and ends at 130, so the total length of the Y-axis is calculated as the difference from the starting point and

the ending point. Then, the total length is divided by the value, which is slightly bigger than the maximum number of puffs, and this value is used for calculation of the steps of the Y-axis.

The X-axis for this graph starts at 25 and ends at 300. Each step of the X-axis is calculated by finding the difference between the starting point and the ending point, which is divided by the array_count. Here, the array_count contains the total number of dates. The number of dates is calculated from the first date when a reading is taken until the last date a reading is taken. In the graph, this puff number is shown with a black, curved line.

As an example, we have a screenshot for a specific user. From this screen shot (Figure 5.2.5), we can see the user's number-of-puffs graph, which is represented by a black, curved line, and the peak-flow graph which is represented with a green line. Both the number of puffs and the peak-flow graphs are drawn based on the time. This graph is helpful for the doctor to understand the patient's actual situations. By utilizing this graph, it is easier for the user to acquire knowledge about his/her sickness level.

5.3 JOURNAL AND REPORTS

There is one more tab-bar button on the home screen named "Journal." When the user clicks the "Journal" button, he/she enters a new screen. This screen actually shows a table that contains all the inputs for one user. Each line contains an entry made at a given time by the user. The table contains four columns: date, time, color and report.

Figure 5.3.1: Journal and Report page

A query is made on the database's "peakFlow" table to get all of the dates and times that a person entered his/her Username. With this query, all the dates and times from the starting date/time when a reading was taken and until the last date/time when a reading was taken are available for each user.

The value of the color column is green, yellow or red based on the peak-flow result. Here, the peak-flow result is calculated by utilizing the user's current peak-flow number and the "best" peak-flow number that the user gave when opening his/her account. To get the user's current peak-flow number, a query is written on the database's "peakFlow" table and kept the result in a variable named "CurrentPeak." Another query is written on the database's "users" table to get the user's initial peak-flow number and kept in another variable named "peakUser." Then, the CurrentPeak is multiplied by 100 and finally divided it by the peakUser which is the percentage value for the peak-flow result.

When the value of the peak-flow result is greater than 80, the color is green. This color indicates that the user is safe now, so he/she can continue the medicine being used for asthma. When the value of the peak-flow result is greater than 50 and less than or equal to 80, the color column value is yellow, indicating that the user's condition is stable, but he/she should visit a doctor as soon as possible. Until visiting a doctor, the user continues the medicine that he/she was using for his/her asthma problem. When the value of user's peak-flow result is less than or equal to 50, the color column is red, indicating that the user's condition is not safe. The user should immediately visit a doctor for his/her asthma treatment. Perhaps, the medicines that he/she is using are not the correct ones for this situation. The user should visit his/her doctor as an emergency patient.

The last column for the table is report. A link is kept in this column. Clicking the link lead to a new page. In this new page the user can see his/her recent peak-flow numbers, trigger information, symptoms and the number of puffs. In order to show the

date/time and the patient's current peak-flow number, a query is made on the database's "peakFlow" table. Another query is written on the "Inhaler" table to display the user's recent peak-flow number. In the same way for displaying the user's trigger's information, such as the trigger type and trigger description, a query is made on the "triggers" table. Additionally, another query is made on the database's "symptoms" table to show the user's latest symptom description.

5.4 APPLICATION DESIGN

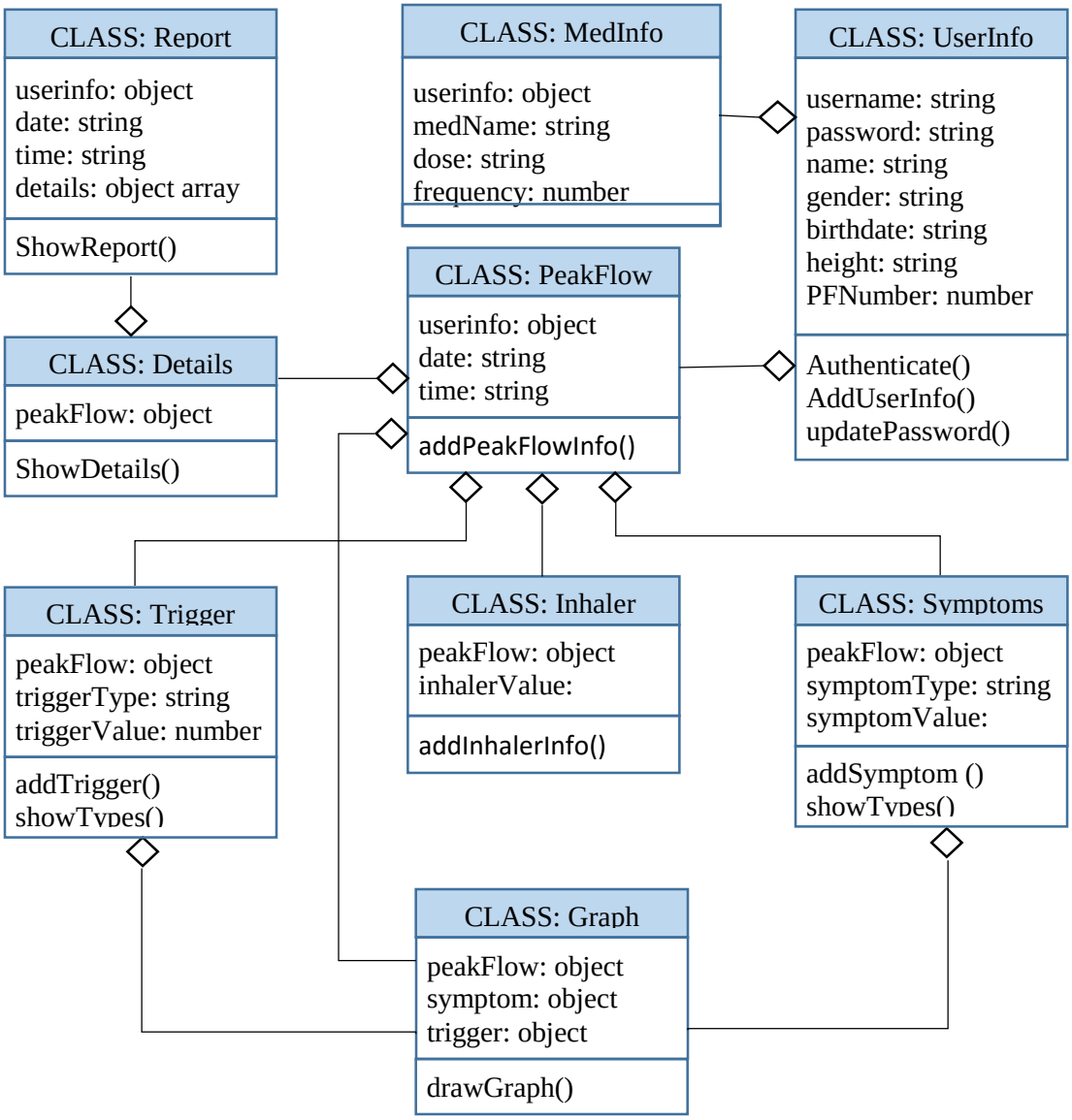

Figure 5.4.1: Application class diagram

The UML diagram shows the relationship between the classes. Here is the details description of the classes and their associations.

5.4.1 USERINFO CLASS

Userinfo class is responsible for managing user information, such as username, password, first name, last name, gender, date of birth, height, peak flow number. This calls provides facilities for adding, deleting, and updating users' information. This class is also responsible for the user authentication. Userinfo class in the used by other classes. This class doesn't contain any reference of other classes. PeakFlow and Medinfo has 1..* relationship with the Userinfo class.

5.4.2 MEDINFO CLASS

Medinfo class contains users' medicine information. This class contains medicine name, dose, and frequency. This class can contain more than one users' information. It has a 1..* relationship with the Userinfo class.

5.4.3 PEAKFLOW CLASS:

PeakFlow class contains users' peak flow information. This class also contains the date and time of the user entry. This date and time is used as a unique key to identify a user input. peakFlow is a key class in the application. It has 1..1 association with the Symptom, Trigger, and Inhaler class. It also has *..1 relationship with the Graph class, and 1..1 relationship with the Details class. PeakFlow can contain multiple user information. It has a 1..* relationship with the Userinfo class.

5.4.4 INHALER CLASS

The Inhaler class contains users' inhaler consumption information such as the number of puffs. This class has a 1..1 association with the peakFlow class.

5.4.5 SYMPTOM CLASS

The symptoms class contains asthma patients' symptoms information. This class is associated with the peakFlow class in an 1..1 relationship. There can be different types of symptoms for asthma. All possible symptoms are presented to the user through this class. This class contains the symptom type and value information. This class also has *..1 relationship with the Graph class.

5.4.6 TRIGGERS CLASS

Triggers class contains information about the triggers to which the users are sensitive from. There can be different trigger types. This class contains trigger type and the trigger value. This class has a 1..1 relationship with the peakFlow class. This class also has *..1 relationship with the Graph class.

5.4.7 REPORT CLASS

Report class is responsible for representing the report entries. Report class contains the list of the entries for a particular user. This class contains an array of Details class objects. This class has a 1..* relationship with the Details class. This class also has 1..* relationship with the peakFlow class.

5.4.8 DETAIL CLASS

Details class represents the detail information about a single entry made by a single user. This class has 1..1 relationship with the peakFlow class. One peakFlow entry is represented by a one instance of details class.

5.4.9 GRAPH CLASS

Graph class is responsible to present the information in the form of graph, bar chart, or pie chart. This class contains peakFlow, trigger and symptom information. This class has a 1..* relationship with PeakFlow, Trigger and Symptom class.

5.5 DATABASE DESIGN

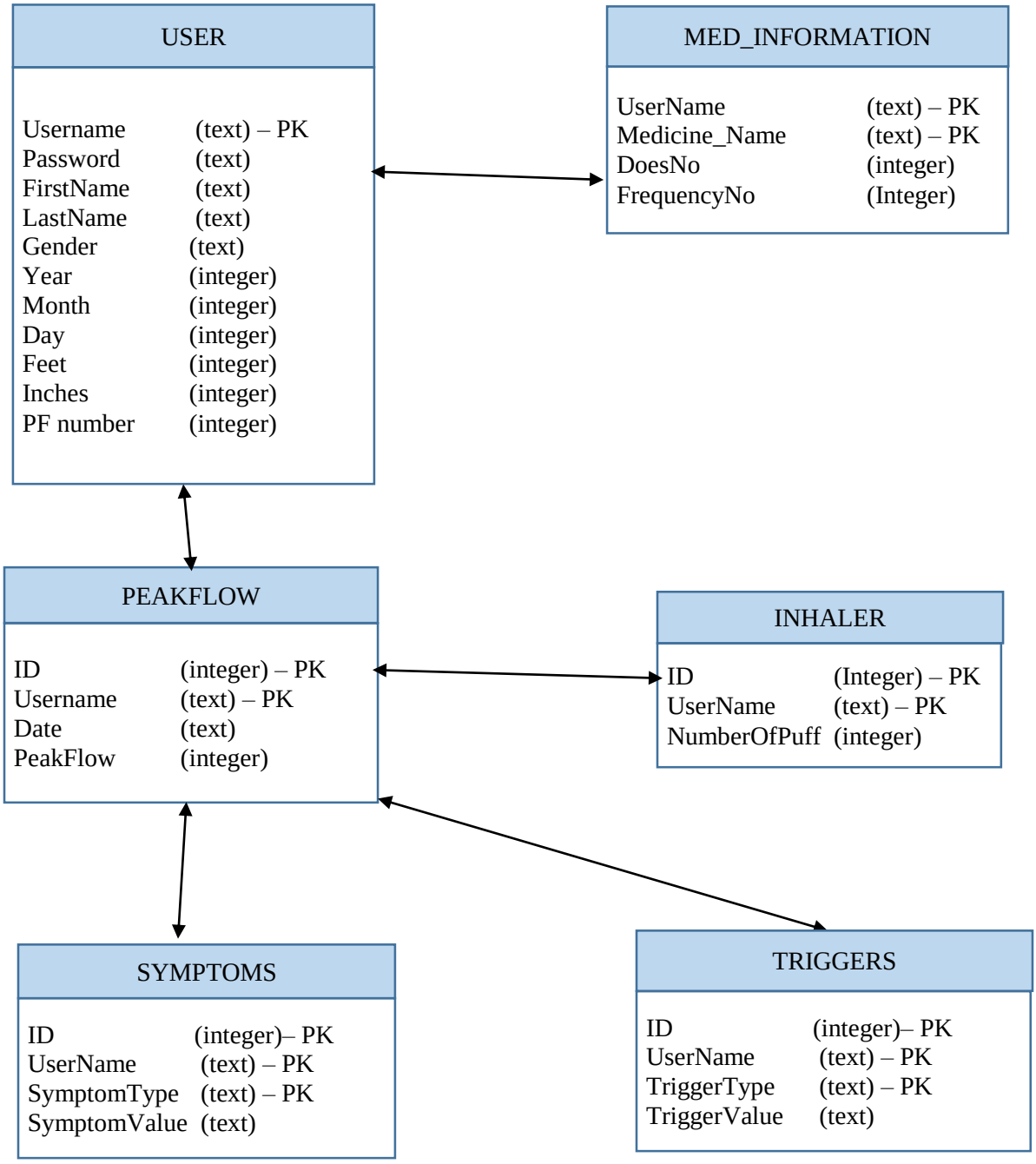

Figure: 5.5.1 – Database ER Diagram

The database design is rather straightforward. The user table contains user information. The username is the primary key for the user table. The peakFlow table contains multiple user information and has the username as a foreign key. The trigger, symptom, and the inhaler class has one to one relationship with the peakFlow table. Medicine information is stored in the Med_information table. Med_information has one to many relationship with the user table.

CHAPTER 6: EVALUATION

6.1 EVALUATION OF THE APPLICATION

This asthma patient information-collection mobile application is evaluated by walking through the scenarios and by validating if the application is capable of helping the patient in all situations. This evaluation can be divided into different phases. Phase one describes how easy it is to input different patient information, how easily the patient can enter the information (symptoms, triggers or peak flow), and if this data entry is feasible or comfortable. Phase two verifies how valuable the collected information is, and how the information can be used. Phase three evaluates how the expert/doctor can be benefited, how the data is presented, and if this data is meaningful.

6.1.1 PHASE ONE

In phase one, it is shown how easily the data can be entered by using this mobile application. We demonstrate the application's usability with an example for a patient named "X" who has an asthma problem. Let us assume that patient "X" is using this data-collection mobile application. The patient uses this app to provide data for his asthma condition. The first, easy step that patient "X" needs to follow is to open the application and to create his account by pressing the "Sign Up" button. The doctor or the medical associate can help patient "X" to create his/her account. While creating the account, patient "X" needs to give his/her current medicine information for his/her asthma problem. The doctor or the medical associate can also help patient "X" to enter the medicine information. Once the initial information entry is completed, the application

is ready for patient "X" to use. Every time that patient "X" needs to log in to the application, he/she will just open the app, and the pop-up message for logging in will appear. He/she can log in by providing his/her credentials and by pressing the “Login” button. After logging in, patient "X" can get the app’s home screen which is very self-explanatory. Here, he/she presses the “Date” button to get the calendar and to select the actual time and date for which he/she will add the first data entry. The default value is the current time; hence the patient actually just needs to press the “OK” button in most cases. He/she needs to adjust the date/time only if he/she wishes to enter data which he/she did not update in time in the past. Let us assume that patient "X" suffered from some symptom and that he/she wants to store this symptom information. In order to provide his/her asthma-symptom input, he/she needs to press the “Symptoms” button, and he/she can find some common symptom names with the images. The images and the description are self-explanatory, and the data entry is very user friendly. He/she just needs to know which symptom he/she is facing and needs to press that symptom button. After pressing the appropriate symptom button, he/she gets the details about that symptom and can easily select one of them. All this information is saved in the database when he/she goes back to the home screen and press the “Submit” button once all entries are completed. When the doctor opens the report, he/she can see all the information that is given about patient "X"'s asthma symptoms, including the time and date. In this way, every asthma patient who is using this app can easily enter his/her data from time to time, and all the entries are saved so that his/her doctor could realize his/her situations.

Similarly, “X” has also suffered from some triggers, and he/she wants to store the trigger information as he/she did with the symptom information. Now, he/she just need to

press the “Trigger” button from the home screen, and he/she is able to find three types of triggers: Indoor triggers, Outdoor triggers and Others triggers. In order to give his/her trigger input, he/she just needs to press one or more of the three trigger buttons to find some common trigger names with the images. The images and the text are self-explanatory and are very easy to understand. Therefore, the user just needs to know which triggers he/she is facing and selects them. Then, he/she can go back to the home screen using the “Back” button, and all the trigger information is saved in the database when he/she presses the “Submit” button after all information is entered. User can go back to any of these entry pages and can modify the information until he/she presses the “Submit” button. Once the “Submit” button is presses, all information is saved in database, and user cannot make any further modification to the information.

Whether the patient is using an inhaler regularly can be entered by pressing the inhaler button. If the patient is using an inhaler, then he/she can also enter the frequency, and the entry is saved by pressing the OK button. In this way, any asthma patient can enter his/her triggers, symptoms, peak-flow numbers and inhaler-use information easily. He/she can save the information from time to time by using this mobile app.

6.1.2 PHASE TWO

In phase two, it is shown how valuable the collected information is and where we can use that information. When any patient enters data about his/her symptoms, triggers, dates, peak-flow numbers and inhaler information, everything is saved in the database immediately. Based on that information, the trigger pie chart, symptom pie chart and date-peakFlow-inhaler graphs are drawn by using different colors.

Let us assume that patient “X” enters his/her symptoms. X has a cough, shortness of breath and a sleep problem. When he selects those three symptoms using this app, the information is saved in the database’s “symptoms” table. The percentage ratio for the user’s asthma symptoms has been calculated by counting the number of symptoms for patient X using a query of the database’s “symptoms” table. Finally, the pie chart is drawn using different colors and is based on that percentage ratio.

Similarly, the trigger pie chart and the date-peakFlow number-inhaler bar graph are generated when patient X enters of his/her trigger information, inhaler use, peak-flow number and date information using this mobile app.

The app’s report page is generated based on that given information. This report page shows the asthma patient’s details, such as his/her trigger types and descriptions, symptom type and descriptions, current peak-flow number and inhaler information, based on the specific time and date. The most important column for the Report page is color. When seeing the color(s) on the report page, an asthma patient can realize his/her current health condition and, if needed, can take immediate action to change the treatment plan. This column has green, yellow or red; the column is generated by patient’s peak-flow results. These results are calculated with the user’s current peak-flow number and the peakFlow number which he/she gave when he/she created the account.

6.1.3 PHASE THREE

In phase three, it is evaluated how the doctors can benefit from this mobile app for asthma patients. When an asthma patient goes to his/her doctor, the patient just needs to show the Report page and the graph page to the doctor. From the Report page, doctor can easily see all the patient’s information. The Report page contains the details about the

patient's collected information. Each report contains detailed information for a specific time. On the other hand, the graph and pie chart present an overall view for the data. The graph and chart are useful to understand changes in the symptoms, triggers, peakFlow and inhaler consumption.

Let us consider a scenario where patient "X" visits the doctor and the doctor see his/her peakFlow graph. If the doctor can find frequent increase in the peakFlow, he/she can change the treatment plan based on the output that is observed in the graph. Similarly, the doctor can view the pie charts for symptom and triggers, and can get a clearer idea about which specific symptom or the trigger the patient has sensitivities. For any specific period or a specific date, if the doctor needs more information, he/she can locate the specific report and obtain all necessary details about the readings taken for the period or date. Thus, the report and the graphs can be very beneficial for the doctors. These can provide real and meaningful representations of the patient's actual condition.

From the above discussion, it can be concluded that the application's different features are well justified to serve the purpose that they are meant to have. Comparison with the features of other popular asthma patient data collection applications, such as AsthmaMD, Breathe, and ASCO will justify this fact. For example, AsthmaMD is missing with the Inhaler information collection feature, Breathe is missing with the Inhaler, PeakFlow features, ASCO is missing with the Inhaler, PeakFlow, and Trigger information collection features. All these features are available and fully function in our asthma patient data collection application. Furthermore, this application has information representation feature which is not available in many other applications, such as ASCO, and Breathe.

CHAPTER 7: CONCLUSION

7.1 SUMMARY

Because collecting patient information is essential with asthma, the importance of a mobile-based application is obvious. The iPhone platform is chosen for this thesis work in order to perform the necessary development. A full-fledged iPhone application is developed to collect and present the asthma patient's information. In summary, the application has the following features:

- This application provides a user-authentication mechanism, so having the phone does not allow a person to enter information unless the credentials are provided. Thus, the information is always secure.
- The iPhone application provides a very user-friendly menu from which different features can be chosen.
- The iPhone app has the capability to collect all the crucial information for an asthma patient, including the peak flow, symptoms, triggers, inhaler use and medications.
- The iPhone app has images and videos which make most of its menus self-explanatory.
- Most data entries are touch based rather than typing the actual value, making the data entry much easier for patients.
- The data are collected in database and are saved. A large amount of data can be collected and stored without much performance impact.

- The data are presented in graph, chart and tabular format, giving a nice and easily understandable representation of the data.
- Detailed reports are prepared for each time period, which can be very helpful to understand the patient's condition at different times and for communication with health providers.

7.2 CONTRIBUTION OF THIS THESIS

This thesis describes the development of an iPhone application that can be used to collect the asthma patient's information in very easy steps. Research is performed to identify the application's necessary features. Once a feature is finalized, the database design is performed. An iterative design approach is taken, and the database design is completed in a couple phases. Research about how to improve the application interface is also conducted so that the data entry is really easy for the patient. Thus, mostly image-based data entry is introduced in the application; in most cases, the patient does not need to enter the information. Research is also conducted about how the data can be represented in a more meaningful way and how the data's visual representation can be improved.

7.3 FUTURE IMPROVEMENTS

There is scope for further improvements of the application. First, a web database can be implemented and integrated with the application. Information can be stored in this web database. Information from this web database can be collected for multiple patients. This data can be analyzed and can be processed to find a general trend. Information discovery is possible using the information, and the knowledge can be used by many

other patients. Second, automation can be implemented to send the information to the doctor. Currently, it is only possible for the patient to send information to the doctor by physically showing the graph and chart to doctor by using the phone. After the improvement, it will be possible to send an email with the necessary information. Furthermore, it will be also possible to share the information on the web.

BIBLIOGRAPHY

1. A. Hamou., S. Guy, B. Lewden, A. Bilyea, F. Gwadry-Sridhar, M. Bauer, "Data collection with iPhone Web apps efficiently collecting patient data using mobile devices," e-Health Networking Applications and Services (Healthcom), 2010 12th IEEE International Conference on , vol., no., pp.235,239, 1-3 July 2010

2. Pew Research CenterInternet, Science & Tech , "Mobile Technology Fact Sheet", http://www.pewinternet.org/fact-sheets/mobile-technology-fact-sheet/

3. D. Low, A. Pittaway, "The 'iPhone' induction - a novel use for the Apple iPhone. Pediatric Anesthesia", 2010, vol18, pp 573-4.

4. National Heart, Lung and Blood Institute (NHI) "Guidelines for the Diagnosis and Management of Asthma (EPR-3)", http://www.nhlbi.nih.gov/health-pro/guidelines/current/asthma-guidelines

5. Usability.gov, "User-Centered Design Basics", http://www.usability.gov/what-and-why/user-centered-design.html

6. Attune, "mHealth - Its Advantages & Disadvantages", In Healthcare IT, December 26, 2013, http://attunelive.com/blog/mhealth-its-advantages-disadvantages

7. mHealth, https://en.wikipedia.org/wiki/MHealth

8. S. Burdette, T. Herchline, R. Oehler, "Practicing medicine in a technological age: using Smartphones in clinical practice", Clinical Infectious Disease, 2008, vol 47, pp117-22.

9. Gamble K. Beyond phones. Healthcare Informatics 2009;26(8):23-6

10. D. Leonard, and J. Tozzi, "Why Don't More Hospitals Use Electronic Health Records?", Bloomberg Business, June 21, 2012

11. Poimapper, Mobile patient data collection application, http://www.poimapper.com

12. Open Medical Record System (OpenMRS), http://openmrs.org

13. L.P. Boulet, R. Phillips, P. O'Byrne, A. Becker, "Evaluation of asthma control by physicians and patients: comparison with current guidelines", Journal of the Canadian Thoracic Society, 2002, vol 9(6), pp 417-423.

14. V. Goncharuk, ” Voalte's view on the present and the future of the iPhone platform for the medical sector”, http//iphonemedicalapps com/ 2010 [cited 20100 Jan 19];

15. B. Falchuk, “Visual and interaction design themes in mobile healthcare”, 2009.

16. J. S. M. Belisario, G. Greenfield, J. Car, L. H Gunn, "Smartphone and tablet self-management apps for asthma", Article in COCHRANE database of systematic reviews (online), NOVEMBER 2013

17. Apple, “Advancing health care with iPhone”, http://www.apple.com/iphone/business/profiles/memorial-hermann/ 2010 [cited 20100 Jan 19];

18. medgadget.com, “FitnessBuilder monitors at-home physical therapy progress”, http://www.medgadget.com/archives/print/008884print html 2010 [cited 20100 Jan 19];

19. Apple, “Using iPhone to improve patient care”, http://www.apple.com/iphone/business/profiles/diamond/ 2010 [cited 20100 Jan 19];

20. SYS-CON Media Inc, “100,000 physicians actively use Epocrates on the iPhone”, http://au.sys-con.com/node/1045098/print 2010 [cited 20100 Jan 20];

21. “New and noteworthy iPhone medical apps released last week in app store”, http://iphonemedicalapps com/ 2010 [cited 20100 Jan 20];

22. B. E. Himes , I. S. Kohane, M. F. Ramoni, S.T. Weiss, “Characterization of Patients who Suffer Asthma Exacerbations using Data Extracted from Electronic Medical Records”, AMIA Annual Symposium Proceedings, 2008, pp 308–312.

23. Smart Insights, “Mobile App Statistics, July 2014 round-up”, http://www.smartinsights.com/mobile-marketing/app-marketing/mobile-app-statistics

24. J. Anhøj, C. Møldrup, “Feasibility of Collecting Diary Data From Asthma Patients Through Mobile Phones and SMS (Short Message Service): Response Rate Analysis and Focus Group Evaluation From a Pilot Study”, Journal of Medical Internet Research, Vol 6, No 4 (2004)

25. ASCO, “Cancer and Asthma patient data collection application”, http://www.cancer.net