Big Data and mHealth Drive Asthma Self-Management

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***Abstract*—This paper reports our effort to establish the desirable characteristics for the next generation asthma APP for an underserved population. Proposed asthma mobile APP aims to promote older adults' positive adjustment to this chronic disease by being an effective tool for patients to track their personal asthma triggers, predict asthma attacks, support asthma self-management and communicate with healthcare provider. Management of asthma is a dynamic process and varies by individual. For that reason, a personalized asthma APP is necessary to control this chronic disease. Environmental indicators, personal triggers, symptoms monitoring, medication use, peak flow, and blood oxygen monitoring data are analyzed to predict an asthma attack or indicate control. Other non-asthma symptom monitoring, such as fatigue, and biometric measures, like blood pressure, may be added as requested by end user.**

Keywords—eHealth; asthma; self-management; big data analysis; machine learning.

I. INTRODUCTION

Asthma and Chronic Obstructive Pulmonary Disease (COPD) are the chronic conditions that are presently incurable but their symptoms can be controlled through quality health care, appropriate medications, and good self-management skills [1]. Unlike COPD, the airway constriction of asthma is reversible with treatment. However, if not treated early and effectively, asthma can lead to COPD, which may worsen over time and cause permanent damage to the lungs. About 40% of COPD patients have asthma and this dual diagnosis increases with the age of the patient [2].

A. Asthma Prevalence Depends Mostly on Age, Gender, Income, and Race

Asthma prevalence is higher among children, females, and low-income populations, varying by race and ethnicity. Children have higher asthma prevalence (9.5%) compared to adults (7.7%). Females have higher asthma prevalence than males (9.2% compared with 7.0%). People of multiple races have the highest asthma prevalence (14.1%), while Asians have the lowest rates (5.2%). Blacks (11.2%) and American Indian or Alaska Natives (9.4%) have higher asthma prevalence than whites (7.7%). Among Hispanic groups, asthma prevalence is higher among people of Puerto Rican descent (16.1%) than those of Mexican descent (5.4%) [3].

More than two million Americans age 65 and older have asthma. Comparing the prevalence of asthma between different age groups of those of age 24-64 and those 65+, the higher age group, have a higher prevalence [4]. Older adults represent the fastest growing segment of asthma sufferers in the US. Asthma patients over age 65 are at the highest death rate (0.58 per 1,000 patients compare to 0.15 per 1,000 patients younger than 65) [4]. Asthma may not be as dangerous a disease for younger patients as it is for older adults whose disease may be fatal.

B. Treatment and Diagnosis of Elderly Is More Difficult

As people age, the reduced elasticity of an older adult's airway makes asthma and COPD a common health problem in people over age 65 [5]. Also, the brain, which controls the functioning of breathing, may lose some of its function and the nerves in the airways are not as sensitive as before. In addition, the immune system of an older adult is weaker and less able to fight some lung infections [5].

About half of the total adults in the US have at least one chronic disease, and one out of four adults have multiple chronic health conditions [6]. Taking multiple medications may precipitate side effects. Adjusting medications to reduce, or eliminate, side effects is often undertaken heuristically. The case of multiple medications is exacerbated by the ongoing physiological changes in the patients and the gradual, subtle but unrelenting, worsening of the disease. For the elderly patients, this compounding of treatments and time-related progress of asthma itself makes the diagnosis difficult; and that in turn, leads to greater prevalence as well as highest mortality rates. Moreover, the older adults are vulnerable to developing social isolation and often manifest negative adjustment to asthma.

C. Current Asthma APPs

Recently, research was conducted to evaluate the effectiveness of 103 selected Android, Apple, Blackberry, and Windows Phone asthma apps as a tool to support asthma diagnosis or asthma management. The research indicated that within two years, the number of asthma apps doubled. However, even the newer apps are not providing comprehensive information such as the use of action plans or support guidance consistent with evidence. There are just a few apps that offer consistent guidelines and evidence-based instructions. About 50% of asthma apps offer only basic asthma information. Only three out of 56 apps in this category meet the standard of comprehensiveness of information about asthma. Half of the apps provide tools for asthma self-

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management. However, there are very few apps that effectively provide the complete features of an asthma self-management tool such as diaries and tracker, rescue and maintenance medication use, pollen status, pollution status, and allergen database. None of the apps propose comprehensive guidance for lay management of acute asthma, including pharmacological and non-pharmacological treatments [7].

Many smartphone asthma APPs have been developed to support asthma patients' self-management of the disease. Asthma APPs are still in the infancy stage of development. A literature review indicates satisfaction to be equivocal. Moreover, available APPs have many unresolved issues, such as: (1) No APP provides comprehensive asthma information while at the same time possessing the characteristics of an efficient tool for self-management of the disease; (2) No APP has the ability to integrate data from disparate formats; (3) No APPs provide comprehensive two-way communication between patients and Health Care Providers (HCPs) to support provider decision making; and (4) No APP targets older adults [7].

TABLE I. ASTHMA APP FUNCTIONS AND AVAILABILITIES

Function Group	Function Availability Among 147 APPs		
	Function	***n***	***%***
Information		***83***	***56%***
	General information	74	50%
	Acute asthma management	23	16%
	Inhaler technique guidance	12	8%
	Other therapeutic instructions	16	11%
Self-management		***70***	***48%***
	Diaries and trackers	36	24%
	Pollen status	12	8%
	Pollution status	9	6%
	Allergen database	7	5%
	Forum	1	1%
	Online Pharmacy	1	1%
	Combined with information	9	6%
Assessment		***16***	***11%***
	Physiological measurement	3	2%
	Assessment questionnaires	11	7%
	Standalone calculations	4	3%
Therapeutic		***6***	***4%***

[a] a. Source: Apps for asthma self-management: a systematic assessment of content and tools [10].

II. PURPOSE

The paper reports our efforts to establish the desirable characteristics for the next generation asthma APP developed specifically for a population segment not presently served, that is, adults age 65 and older. We describe the design and development of a universal asthma APP that promotes older adults' active participation in management of their asthma. The APP will be an effective tool to manage asthma triggers, track symptoms and medications, predict asthma attacks, and support communication with HCPs. It is expected to be an effective self-management and monitoring tool that includes comprehensive information about the condition.

III. METHOD

Components of asthma care include a) assessing and monitoring severity, b) controlling symptoms through appropriate use of medications, elimination of triggers, and treatment of acute/ chronic comorbidities that impact asthma, and c) including individuals with asthma as partners in care [8].

An asthma attack happens suddenly or develops slowly over several hours or days. The severity of asthma may change over time. The severity of a patient's asthma is determined by the number of asthma attacks in a given time period, the degree of airway obstruction during daytime and nighttime, the number and types of symptoms, duration, medication history, and the interfering level of normal activities. These severity levels can be classified as intermittent, mild persistent, moderate persistent, and severe persistent.

Tracking symptoms and severity is one most effective method to identify what makes asthma worse. Controlling triggers by developing a suitable asthma action plan can keep asthma under control. Asthma attacks are usually predictable if a patient's asthma triggers are identified. Correct doses, frequency of daily medications, and immediate use of rescue inhalers are essential to preventing a patient's asthma from worsening.

Environmental triggers are one of the main causes of asthma. According to the CDC, since 1980 the number of asthma patients has increased at an extremely rapid rate. The number of asthma population in 2010 (8.7%) was nearly triple the number of asthma patients in 1980 (3%) [9]. This statistic suggests that environmental factors play a key role in the incidence of asthma,. Asthma patients, therefore, must avoid going outdoors when the pollen count is high, as well as with windy and dusty conditions, high or low humidity, and extreme temperatures to prevent an asthma attack.

Methods for combining data stored in different formats have been and continue to be a challenge. We are working on methods to combine Big Data (BD) with individual data for stream (real-time) reasoning and decision-making. Individual data includes personal determinants and unique self-management data. More specifically, we are developing algorithms for abstracting data from health-care databases to fit the peculiarities of the disease for each case. Since the triggers of the disease are variable (and numerous), combining data from multiple sources to render a trigger profile for individuals will be demanding. Of course, of necessity, the trigger profile will be a "living" document, i.e. self-adjusting over time.

The three main components of the proposed APP are listed below:

A. Tracking Asthma Severity

The APP will keep track of the patient's asthma management information by allowing patients to create an

asthma diary. This feature of the APP helps monitoring an individual's asthma severity and medications. Patients are required to input their daily long-term control medications, rescue medications, immunotherapy (allergy shots), peak flow measures or oxygen saturation levels, emotion state, symptoms, duration, time, and activities while getting an asthma attack and person-specific triggers. The APP will detect the location of the patient when the asthma gets worse to seek the environmental data of that place and see if there is any specific environment characteristic that is likely to cause onset of attack or increase the severity of an ongoing one. User then needs to record heart rate and blood oxygen level by placing his/her fingertip on the camera of a smart device like the iPhone or iPad. In addition, the user can subjectively measure intensity of asthma attack and degree of relief using a sliding scale from 0 (none) to 10 (extreme). The diary allows the user to track activities that minimize or aggravate symptoms.

By analyzing the blood oxygen level, peak flow, and the patient symptom severity level, the patient's personal asthma triggers can be identified. The data collected during this process can also be used to determine if the current asthma action plan is working. If the current action plan indicates shortcomings, an improved plan could be devised. All of this information assists patients and HCPs in determining if asthma is under control and helps adjust patient's medications regimen accordingly.

B. Asthma Attack Predicting

Individual triggers are best determined by allergen testing by an expert; however, individuals may realize triggers without this testing. For example, exposure to smoke, dusty conditions or a drop in barometric pressure may be observable triggers easily recognized by an individual with asthma. The data of individual triggers is then compared with the environmental data, which is automatically integrated in the APP. From the knowledge of the patient's location, prevailing environmental conditions, such as humidity, pollen, mold, dust mites and air pollution, known to affect Asthma patients, are determined. This data integration feature supports environmental information that can be analyzed together with the patient's individual triggers to predict an asthma attack. To confirm the accuracy of the prediction, a patient is asked to measure his/her blood oxygen data. The APP may also require a patient to perform an exercise challenge and measure the duration, steps, or distance by using the smart device's motion sensor before measuring blood oxygen level. This test measures how a patient's breathing is affected by exercise and can determine if exercising is one of that patient's asthma triggers. It will predict asthma attack based on the severity of patient activities as well. The main purpose of this component is helping patients avoid asthma attacks and optimize control.

C. Asthma Monitoring

If the analysis process indicates that there will be an asthma attack in the near future, the APP will trigger an alert to both the patient and the health provider (if so desired) and suggest some tips to possibly prevent or lessen intensity of an asthma attack. The data that is collected by the APP may also be synchronized with the Electronic Health Record system.

By providing a comprehensive tool, for asthma information and self-management that promotes patient and HCPs communication and supports the decision-making process, the proposed app is expected to provide a comprehensive tool to keep the condition under control and boost asthma patients' positive adjustment to this chronic condition. This is extremely important since asthma treatment depends mostly on how well the asthma action plan is controlling asthma symptoms and preventing asthma attacks.

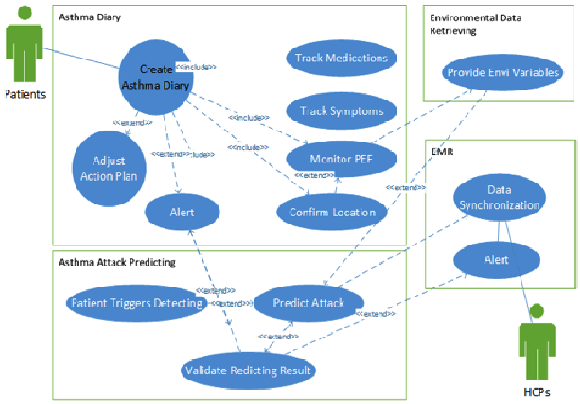

Fig. 1. The Proposed Asthma APP Use Case Diagram.

IV. Conclusion

Management of asthma is a dynamic process and varies by individual. For that reason, a personalized asthma APP is necessary to control this chronic disease. The proposed asthma APP will identify personal triggers and accordingly predict an asthma attack based on the evaluation of environmental indicators, personal triggers, peak flow, and blood oxygen monitoring data.

Different sources of data often imply data stored in inherently different formats. The integration of such data, culled from different databases requires use of BD techniques. The use of self-management applications supported with evidence based data analysis is recommended for individuals with chronic diseases.

V. Futute Work And Recommendations

In healthcare, in order to evaluate the effectiveness of a new intervention with sufficient evidence, the differential clinical management of patients between the control and intervention groups should be as low as possible. Usually, a suitable randomized experimental design should be conducted for the evaluation purpose. For an asthma APP evaluation, the equal distribution of patient characteristics that may affect the disease prevalence must be ensured for the validity and reliability of the experiment. Besides, the seasonal nature of asthma and long-term adherence to self- management practices need to be tracked and considered [7].

Any device or treatment meant for Aiding Management of a Chronic Condition will require more through extensive

testing than could be undertaken in the present phase of developing and testing. In subsequent phases, the APP could be augmented and tested for the inclusion of more asthma triggers as well as different populations. In addition, issues such as security, privacy, standards and governance should be carefully considered when developing an asthma APP. These factors play a critical role in the implementation of any healthcare application.

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