Managing Chronic Diseases through connected IT health framework

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Abstract

One of the major health challenges in modern society is chronic diseases. Chronic diseases cause tremendous burden to the society. As elderly population continue to grow, the number of chronic disease patients and corresponding demands for the care will be increased accordingly. Even though chronic conditions may not be cured but most of chronic diseases are preventable if the risk factors of the diseases are monitored and controlled properly. Such monitoring and control may help prevent chronic diseases or delay the chronic conditions from further development. In this paper, we propose a connected health IT framework that incorporates behavioral changes, vital sign management, physical activities, and customized learning to prevent and to manage chronic conditions from various perspectives.

Keywords: connected healthcare framework, chronic disease, Health Capability Maturity Model, lifestyle analysis

1. INTRODUCTION

Chronic diseases are the leading cause of deaths and morbidity in developed countries. Most of population over 60, have 2 or more chronic conditions and this trend increases with age – more with poor and vulnerable. However, in most of cases, chronic diseases are preventable if we monitor and control the risk factors of the diseases properly as we know the cause of the diseases [1]. Risk factors include smoking, alcohol usage, physical inactivity, poor diet, obesity, high blood pressure, and elevated cholesterol. These factors are deeply embedded into general public's lifestyle and, often times, without guided coaching or carefully customized health improvement activities, it is very challenging to change their lifestyle. So the burden of dealing with chronic diseases and corresponding care would be left as burden to society. According to the Centers for Disease Control and Prevention (CDC) in the US, chronic disease accounts for approximately 75 percent of the nation's aggregate health care spending and its impact on US economy is more than $1 trillion per year. In order to alleviate such problem, governments in developed countries come up with new policy frameworks for chronic disease based on disease prevention program and disease management program to treat and delay, reduce emergency hospital admissions with the aim to promote and to improve the health of the population and reduce the risk factors of chronic diseases. Also to promote structured and integrated care in the appropriate setting that improves outcomes and quality of life for patients with chronic conditions. Activities across various sections are presented for the prevention of unhealthy lifestyle factors that contribute to chronic disease, which requires chronic diseases management at different levels through a group of customized activities and the provision of connected health services that are focused on prevention of chronic diseases or maintaining chronic conditions.

Behavioral change to anyone is hard and prone to failure as it requires the change of lifestyle that takes personalized strategy for each individual [2]. For that to be successful, it should start out with personalization phase [7] such as health risk assessment, risk analysis, the analysis of personal lifestyle such as time to wake up, time to get to work, time for lunch, etc., along with monitoring of vital signs and observed symptoms so it may give enough motivation to initiate the behavioral change endeavor. The personalized health goal(s) may accrue from the collected personal data in the initial process. There can be multiple ways to satisfy and sustain health goal(s). To increase the chance to achieve the personal health goal(s) and sustainability, each user must carefully select the activities that they can handle. As each person has different capability in handling the health improvement activities, we categorized those activities in maturity levels using Health Capability Maturity Model (HCMM) [13]. Each level has a defined set of activities that belongs to that level, which means that each user whose health capability maturity level is identified as the same level has comfortable feeling of handing the activities belong to the level. Once the activities that belong to the same or lower level as the user are selected, they need to be embedded into each user's lifestyle routine so the monitoring system does not force the user to go

outside of their daily routine. Embedded activities within daily routine are subject to be managed throughout weekdays. Each activity may be associated with an existing health app – Android/IOS – so it can collect daily reading from each activity. Since each app is used to achieve health goal(s), each app is playing a role of Software as a Medical Device (SaMD) [5] that is defined by the International Medical Device Forum (IMDRF) as "software intended to be used for one or more medical purposes that perform these purposes without being part of a hardware medical device". The review of the collected daily data may be performed and analyze each week day for goal satisfaction. Vital sign measurements such as blood pressure, heart rate, respiratory rate, temperature along with observed symptoms may also need to be collected and used for predictive analytics along with existing personal health records to prepare for the potential upcoming conditions.

As discussed in various articles [2, 7, 10, 13], personalization in preventive care or treatment have positive impact in improving patient outcome. Once the potential diseases or chronic conditions are identified, it is essential to learn about the disease and conditions through customized learning [14] so each user is well prepared for their own condition.

So far, most of medical industry's effort has been paid to find out how people get sick while focusing on why part. However, the future healthcare should focus more on the prediction on how our health is progressing by analyzing the historical data we have collected so we may not run into actual diseases. As it is based on data science and algorithms in analytics, it gives future insights on out future health conditions [9, 10, 11].

The rest of the paper is organized as follows: section two discusses about the related articles, our proposed framework is discussed in detail in the section three, and finally section four conclude the paper.

2. RELATED WORK

As elder population continues to grow, the treatment and care for chronic diseases is becoming significantly short-handed and resources for such care are thin spread, which results in reducing the quality of care. There have been numerous approaches in handling chronic diseases ranges from preventive care and effective treatment to public health policy.

According to World Health Organization (WHO), the leading chronic conditions are listed as Neuropsychiatric, Cardiovascular, Cancers, Respiratory, Unintentional injury, and Musculoskeletal. Patients with such chronic conditions are heavy users of the health services. Under certain circumstances, such services may not be affordable so the quality of life inevitably goes down. In the article, published by dept. of health and children, Ireland [1], the risk factors are categorized as Smoking, Excess Alcohol, Cholesterol, Blood pressure, Overweight, and Sedentary. These risk factors cause multiple chronic conditions. They suggested that disease the national focus should be given to prevention and health promotion, connected healthcare, and monitoring and evaluation framework. [1, 4]. As for the personalization of care, Hans-Peter Brunner-La Rocca, et al [2] suggested personalized management of chronic diseases along with associated challenges. Etienne Minvielle, et al [7] proposed a framework for the customization in health care. Mobile app intervention framework for chronic diseases was proposed by Wilhide, et al. [3] to improve clinical evidence and change behavioral activities.

Most of effort in health care has been focused on pathology but with that alone, it may not be possible to prevent chronic diseases. To be effective, the prediction of future health based on previous personal health data needs to be done so patients may be able to prepare for it and hopefully avoid chronic conditions from happening [9, 10, and 11]. Some of the prevention programs can be as easy as push-ups. Justin Yang, et al [8] discovered the relationship between push-ups and cardiovascular disease. Jennifer Bresnick, et al [9] discussed predictive analytics being used as an estimation of the likelihood of a future outcome based on patterns in the historical data. When prediction is available, prevention can go hand in hand.

One of the missing links in patient treatment is the availability of patient generated clinical data that can be used to reduce medical errors as it explains patient's health condition more accurately. However, the use of patient generated clinical data can be quite challenging due to the issues such as reliability, access mechanism, trust, and privacy. Hence it has not been actively used by caregivers in the treatment. To resolve such situation, Stanley Ip, et al [12] proposed a framework to evaluate home tests for use in the management of chronic diseases.

Level	Process Area	Recommended Goal	Related Work
Level 0- initial	• Health assessment • Baseline data collection	• Acknowledge clinical severity, functional status, and problems	Bensley et al. 2004; Garcia and McCarthy 2000
Level 1- repeatable	• Requirement Identification • Health Literacy Education • Self-Measurement Training • Resource Management	• Identify target behaviors for improvement • Develop and sustain self-measurement capability • Acknowledge clinical severity, functional status, problems, and barriers to behavior change and self-management • Obtain evidence-based information	Broderick and Haque 2015; Coulter, Entwistle, Eccles, Ryan, Shepperd 2015; Jia et al. 2015; Mitchell and Begoray 2010; Nutbeam 2000, 2009
Level 2- defined	• Self-Care Management • Technology-based Intervention Training • Risk Management • Decision Analysis and Resolution	• Establish defined processes and goals and identify the priorities for goal achievement • Facilitate to assess the milestones via technology-based intervention (e.g. immediate feedback, text reminder) • Identify potential health problems and mitigating strategies using technology based intervention • Analyze and evaluate possible decisions for the processes	Broderick and Haque 2015; Free et al. 2013; Murray and Frenk 2000; Norman et al. 2007; Oinas-Kukkonen 2013
Level 3- managed	• Quantitative Self-Monitor and Control	• Establish quantitative objectives based on the needs of the current health status	Jia et al. 2015; Meyer and Boll 2014; Simon and Seldon 2012
Level 4- optimized	• Health Promotion Management • New Innovative Evidence-based Health Intervention Adoption	• Focus on continuous improvement based on quantitatively managed processes • Adopt new and innovative technology or support to maintain and/or optimize the current level	Entwistle and Watt 2013; James 2013; Kok et al. 2004; Wandersman et al. 2012; Yardley et al. 2015

Table 1. Health Capability Maturity Level

It is, of course, the best if we don't put ourselves in such situation from the beginning. To avoid chronic health conditions, it is necessary to monitor and control our health and continuously improve our health condition by following a systematically designed healthcare framework. As mentioned in the previous section, Health Capability Maturity Model [13] may be used to improve our health as it is customized to each user's capability to handle the corresponding activities. From the assessment of HCMM, a level is given according to their maturity level in health improvement effort. Each level has a list of activities that a person with corresponding level may feel comfortable to perform. Another part is the awareness of each person's potential diseases. Based on each person's observed symptoms, one or more potential diseases may be identified. If those symptoms show consistency, they may end up with those diseases eventually. So learning about such diseases and take actions on the prevention of the diseases may help avoid such chronic conditions [14].

3. CONNECTED HEALTHCARE FRAMEWORK

Chronic diseases don't have cure so the best way to manage those is not to be in the situation or delay the chronic condition from further development. Managing one's health is multi-faceted activities ranges anywhere from checking vital signs to coordinated care among caregivers. To be effective, the involved activities must be performed according to each individual's personal lifestyle. Any deviations such as outside of available time range or their physical capability, etc. would make the health management effort ended up with failure or ineffective at best. The proposed framework is designed to be customized to work around the user's capability and lifestyle. The main components for the framework consisted of the following:

- Lifestyle scheduler
- Daily activity coach
- Clinical data measurement
- Personal health record system
- Symptom checker
- Health capability maturity model
- Customized learning

3.1 Lifestyle analysis and planning

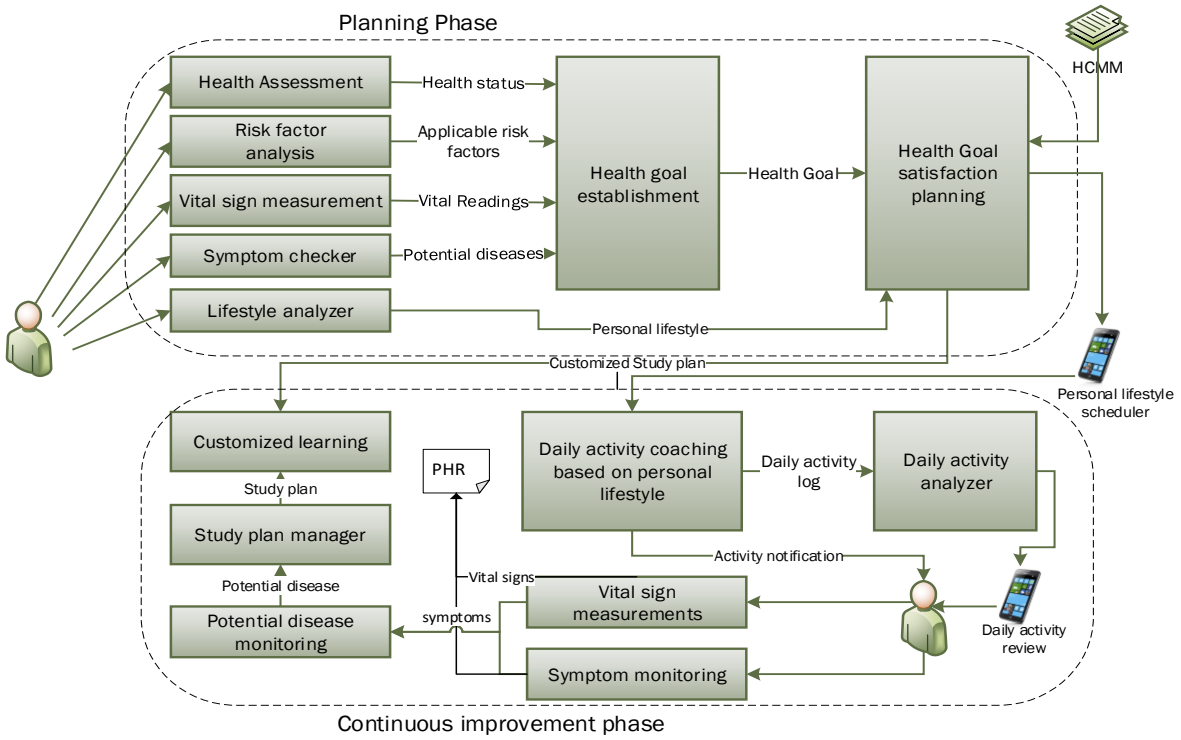

Fig. 1 Connected Health Monitoring and Control Framework (CHMCF)

3.1.1 Health Risk Assessment (HRA)

HRA is the first step to evaluate personal health and its results often motivate users to continue.

- chronic diseases—asthma, cancer, diabetes;
- infectious diseases—sexually transmitted diseases;
- health conditions—disability or pregnancy;
- injury/safety—use of alcohol or seat belts;
- lifestyle—physical activity, diet, tobacco use, sleep;
- occupation—heavy lifting, ergonomics, chemical exposure;
- medical history—family medical history;
- emotional/mental health— stress, depression, anxiety;
- prevention—use of screenings; and
- health literacy—knowledge of resources.

3.1.2 Risk factor analysis

Identified risk factor(s) may go through monitoring and control process.

- tobacco use
  - cardiovascular disease, cancer, chronic lung disease
- the harmful use of alcohol
  - cardiovascular disease, cancer, mental disorder, high blood pressure
- raised blood pressure (or hypertension)
  - cardiovascular disease, kidney disease, stroke
- physical inactivity
  - cardiovascular disease, cancer, diabetes
- raised cholesterol
  - cardiovascular disease, stroke, diabetes
- overweight/obesity
  - cardiovascular, cancer, diabetes
- unhealthy diet
  - cardiovascular disease, cancer, cholesterol, diabetes
- raised blood glucose
  - cardiovascular disease, diabetes

3.1.3 Vital sign measurements

Vital signs such as blood pressure, heart rate, respiratory rate, and temperature are important health indicators. A set of readings at one time is called a "snapshot" and snapshots are collected for comparison and also used for predictive analytics for identifying likelihood of future disease occurrence.

3.1.4 Symptom checker

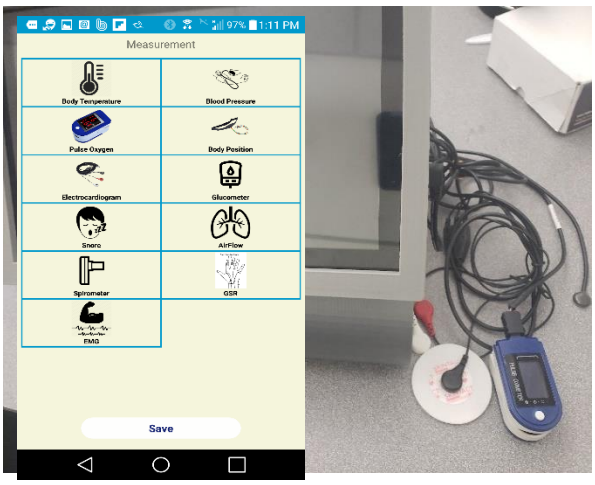

Fig 2. Vital sign measurement device and an Android app

Check for any chronic conditions or potential diseases for frequently recurred symptoms. Any observed symptoms can be used to identify matching potential diseases for monitoring and control.

3.1.5 Lifestyle analysis

Habits, daily routines, behavioral, psychosocial

The collected dataset from these processes are then used by the subsequent modules for planning and analysis.

3.1.6 Health Goal Establishment

The results from the previous modules are used to determine health goals. Health goals may include behavioral changes, diet, weight watch, physical activities, and social and health related activities.

3.1.7 Health Goal Satisfaction planning

In this module, users will determine how to design activities so the established health goal is satisfied. There can be many different ways to satisfy the same goal but depending on each user's capability on health improvement, the type, scope, and strength of activity may be determined.

The HCMM level based activities are selected and embedded into each user's lifestyle scheduler for the monitoring and coaching purpose. The plan is saved into a cloud based spreadsheet file and fed into daily activity coaching module – an Android app that takes the spreadsheet file as input and monitors its activity. The assessment of those activities is done each day to calculate the percentage of compliance.

For each selected activity, corresponding software application is assigned so the data pertaining to the

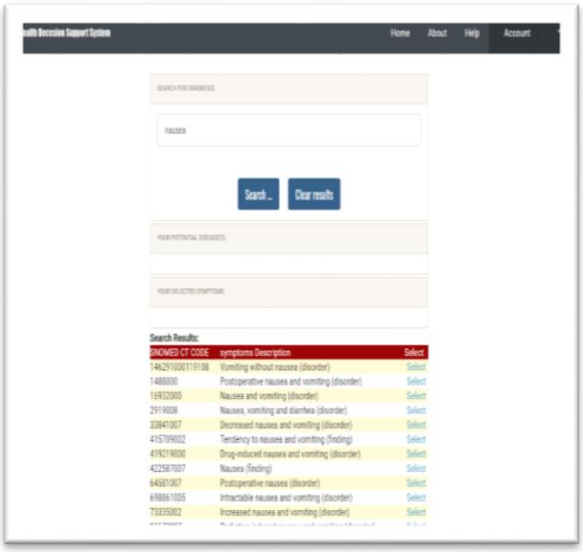

Fig 3. Symptom checking and identifying potential diseases.

activity can be collected and logged into the scheduler for analysis.

The number of mHealth apps available in the market is over 318k (by IQVIA) health apps, which means there are more than enough health apps to choose from. Mobile apps may be used for evidence-based chronic disease intervention [3]. Some of the applicable SaMD apps are "Blood Glucose tracker", "Cholesterol tracker", "Pedometer", "Quit tracker: Stop smoking", etc. In our scheduler, there will be one to one relationship between selected activity and mHealth app.

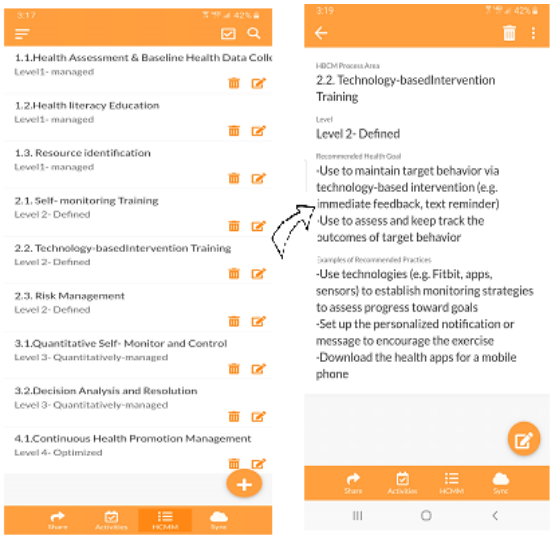

Fig 4. Activities by the levels in HCMM to be used for the design of lifestyle scheduler

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3.2 Continuous improvement phase

After lifestyle scheduler is populated with schedule for the activities and corresponding SaMDs, continuous improvement phase gets started.

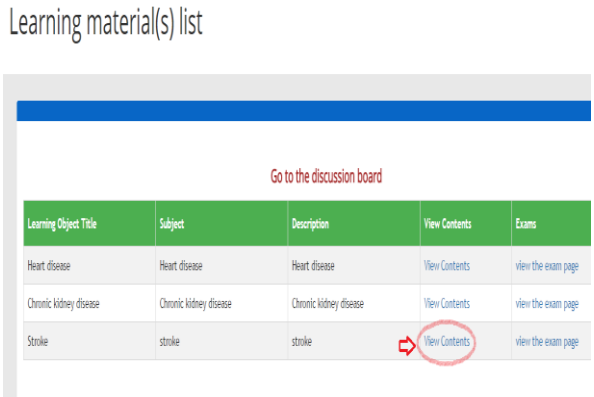
There are 7 processes in this phase:

- Daily activity coaching
- Daily activity analyzer
- Vital sign measurement
- Symptom monitoring
- Potential disease monitoring
- Study plan manager
- Customized learning.

Daily activity coaching will run based on the personal lifestyle with activities. Each activity gets notified to the user when the time comes. The selected mHealth apps will be used to collect activity data to be used for the daily activity analyzer at the end of the day. Vital sign measurement, symptom monitoring, and potential disease monitoring have corresponding mHealth apps for each purpose such as "Track Your Vitals", "Chronic Disease And Treatment", and "CareClinic". Use of symptom checker as shown in the Fig.3 can be used to determine potential diseases from the symptoms and vital signs.

Depending on the health condition of each individual user, there can be multiple potential diseases or some frequently recurring conditions. Since it is differ by person, customized learning materials may be needed to know more about their symptoms and potential diseases or some chronic conditions. The learning materials regarding those may be compiled and generate a study plan for each individual user.

As shown in the Fig. 5, the risk factor of high blood pressure has related chronic diseases, namely, heart disease, chronic kidney disease, and stroke are listed as recommended study plan for high blood pressure symptom. The user with this risk factor will be required to study these learning materials.



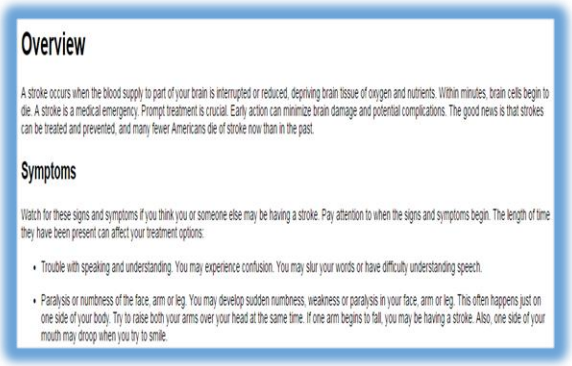


Fig 5. Customized learning materials for high blood pressure and sample content for stroke learning material

4 Conclusion

One of the main challenges a modern society needs to deal with is chronic diseases as they burden the society tremendously. In this paper, we have presented a connected healthcare framework that can help prevent chronic diseases or delay chronic conditions from getting worse. Our proposed connected healthcare framework (CHMCF) allows users to design daily routines based on their lifestyle plus actionable activities that are selected from the activities defined in their Health Capability Maturity (HCM) level so as to satisfy their health goal(s) in a sustainable way. Since those activities are from their own HCM level and are embedded into their lifestyle, they have high probability of survival. As for the monitoring, there are daily review routine and supporting mobile health apps that are used as Software as a Medical Device (SaMD) for each activity. In addition, regular vital sign measurement reading and symptom tracing provide positive predictive analytics for future potential disease monitoring. We also presented customized learning contents for each user so they learn more about their potential or actual chronic diseases and conditions.

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