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Identifying the Components of a Smart Health Ecosystem for Asthma Patients:

A Systematic Literature Review and Conceptual Framework

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ABSTRACT

With asthma being one of the leading causes of death in different countries, the emphasis on improving the health of asthma patients is important. While the use of smart technologies is a good approach for improving the health of asthma patients, technologies need to be connected in such a way that all components of smart health form an ecosystem. However, the components of such an ecosystem has not been identified in literature. The purpose of this chapter was to identify the components of a smart health ecosystem for asthma patients through a systematic literature review. A total of 28 articles met the inclusion criteria. This chapter identified the components of a smart health ecosystem for asthma patients and provided a conceptual framework. The findings of the systematic literature review are expected to inform researchers on the components required for building a smart health ecosystem for asthma patients.

Keywords: Smart Health, Asthma, Smart Technologies, Systematic Literature Review, Smart Health Ecosystem.

INTRODUCTION

Asthma is a chronic inflammatory disease affecting people in different parts of the world (Sinharoy et al. 2018). One of the causes of high prevalence of asthma attacks could be unfavorable weather conditions, lack of medications that have a positive impact on asthma attack in some countries (Sinharoy et al. 2018) and air pollution (Guarnieri and Balmes, 2014). The number of asthma deaths occurring each year is estimated to be about 250,000 (D'Amato et al., 2016). Approximately

300 million people suffer from asthma globally and is a leading cause of disability (Global Initiative for Asthma, 2014; The Global Asthma Report, 2014; World Health Organisation, 2007).

With this growing trend, researchers have developed technologies to improve health conditions for asthma patients. For example, AsthmaGuide, an asthma monitoring system which allows medical practitioners access patient information from a distant location (Ra et al., 2016). Monitoring mechanisms (Kwan et al., 2014, Seto et al., 2009) and prevention mechanisms through technology have been developed (Seto et al., 2009). An emerging term for such applications is known as "smart health" (Sundaravadivel et al., 2018). According to Sundaravadivel et al. (2018), smart health enables patients to take charge of their health through constant monitoring. Iyawa et al. (2016a) and Iyawa et al. (2016b) suggest that digital health enables patients keep track of their health by using wearable and wireless technologies and Rahmani et al. (2018) admit that an ecosystem is relevant in providing meaningful care.

Despite the advancement of patient care through wearables and wireless technologies, these technologies need to be connected. These components of smart health should form an ecosystem in which asthma patients, medical practitioners and technologies can communicate at remote locations. Existing literature support the benefits of having a smart health ecosystem. For example, Chang and West (2006) present a digital ecosystem as an ecosystem that enables the interactions of different components in a digital platform. McLaughlin et al. (2009) are of the opinion that components of a digital ecosystem should work together to share knowledge. The literature further suggests that these benefits are not limited by location (Briscoe and De Wilde (2006). The purpose of this chapter was therefore to provide a systematic literature review on the components of smart health ecosystem for asthma patients and, using these findings, provide a conceptual framework of a smart health ecosystem for asthma patients. The findings of the study contribute to the growing body of knowledge on smart health specifically for asthma patients. Further, this study could provide a better understanding of what is required in developing a smart health ecosystem for asthma patients. The remainder of this chapter is structured as follows: Research Methodology, Results, Discussion, Conclusion and Future Work.

RESEARCH METHODOLOGY

Research questions

The methodology applied in the chapter is the systematic literature review. The systematic literature review aimed to answer two research questions (RQ):

1. What is a smart health ecosystem for asthma patients?
2. What are the components of a smart health ecosystem for asthma patients?

Literature sources

A systematic literature review was conducted on three academic databases: IEEE Xplore, Scopus, and ScienceDirect. In order to identify papers which are not included in the databases, Google Scholar was also used. Google search engine was also used to identify gray literature and non-academic publications relevant to the subject. The following keywords were used to search for relevant papers: (“smart health” AND “asthma”) OR (“smart health ecosystem” AND “asthma”). The publication year was between 2013 to 2018.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for this systematic literature review were:

1. Only publications written in English were included
2. Studies referring to smart health technologies were included
3. Studies not within smart health domain were excluded
4. Studies describing smart health were included
5. Studies around the concept of technologies and asthma were included
6. Studies within the area of smart health relating to other ailment were excluded

Journal articles, conference papers, non-academic papers and practitioner case reports were screened in three phases: title, abstract and full text. A detailed approach to how this was conducted is provided in Figure 1.

Data Analysis and Selection

A total of 625 publications were retrieved from the database search, and 125 publications were retrieved from other sources. 430 duplicate records were removed which left 320 publications to be screened. Based on the title and abstract screening, 73 records were excluded. Out of the 247 full-text articles assessed, only 28 papers were analysed based on the inclusion and exclusion criteria.

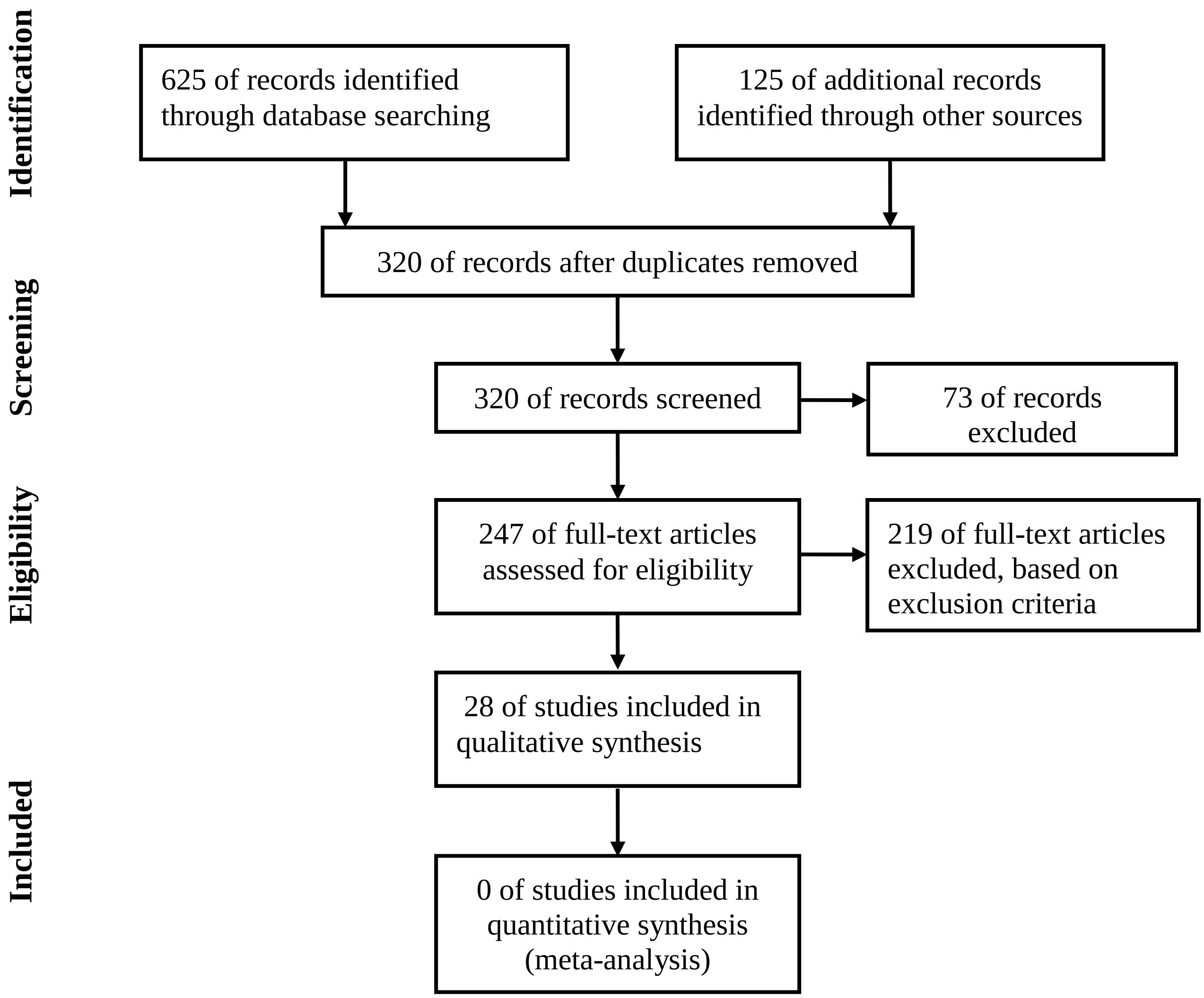

Figure 1 Systematic literature review process (Adopted from Moher et al., 2009)

RESULTS

This chapter analysed 28 papers. Majority of the papers focused on technologies used for smart health. 32 technologies which may be applied in a smart health ecosystem were identified. The findings indicate that smart health has also been discussed around asthma, however, the concept of smart health ecosystem has not been fully determined in the literature; however, this chapter demystified the concept of a smart health ecosystem. The findings helped answer the two research questions which are explained below.

RQ1: What is a smart health ecosystem for asthma patients?

The term *smart health ecosystem* per se was not identified in neither the academic nor non-academic literature. However, discussions on similar concepts were identified in the literature reviewed.

The term *smart health,* also referred to as *s-health,* (Solonas et al., 2014; Zhang et al., 2018) is described as health devices conscious of their environments (Solanas et al., 2014, p.2). *Smart health* is also described as a combination of "m-health and telemedicine to create a novel and richer ubiquitous concept" (Solanas et al., 2014, p. 76). Suzuki et al. (2013), on the other hand, describes *smart health* as the engagement of patients and healthcare practitioners through wireless technology.

Meyer and Boll (2014) defined the three features of smart health systems: a monitoring component, a physical component and a focus on health challenge. Al-Dowaihi et al. (2013) developed an application that illustrates this concept. Their system informs a healthcare practitioner when an asthma patient is having symptoms of asthma attacks. Peak flow meter data is sent to the patient's mobile phone over the Internet to the healthcare practitioner's portal through a server. The study identifies the flow of information between the peak flow meter device, patient, mobile phone, Internet, server, portal and healthcare practitioner with little to no human intervention. This is an example of technology and people working together to solve healthcare problems. Eramo (2018) suggests that technologies should connect asthma patients for integrated care. Suzuki et al. (2013) describes *smart health* as the engagement of patients and healthcare practitioners through wireless technology.

Definitions of a smart health were also provided in both gray and the non-academic literature. For example, Blue Stream Consultancy defines *smart health* as "the technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone". Lee (2011, p.1), on the other hand, defines *smart health* as "medical and public health practice supported by smart mobile devices". Lee (2011) also admits that smart health incorporates ubiquitous technologies. Iyawa et al. (2016a, p.247) suggests that participants of a healthcare ecosystem should be "interrelated" and "interconnected" in a digital platform.

RQ2: **What are the components of a smart health ecosystem for asthma patients?**

Different components of a smart health ecosystem were identified in the literature. These components explain what is necessary for establishing an ecosystem to support smart health monitoring for asthma patients. Different types of components were identified and have been categorized into human and non-human components. Under human components, two main participants to the system were identified: patients and healthcare practitioners (Al-Dowaihi et al., 2013; Thomson et al., 2017, Kikidis et al., 2016). According to Iyawa et al. (2016a), health institutions and organisations are also important components of healthcare ecosystems.

Technologies relevant to a *smart health ecosystem* include peak flow meter device, mobile phones, portal, Internet and server (Al-Dowaihi et al., 2013; Kassem et al.). Rahmani et al. (2018) also indicates that a smart ecosystem should consist of body area sensor network, Internet-connected gateways and cloud and big data support. Suzuki et al. (2013) explain that sensors and wearable technologies are components of a smart ecosystem. Yung-Cheng et al. (2013) point electronic textiles as relevant in healthcare. Wireless communication is also necessary for this technology (Suzuki et al., 2013). Social media was also pointed out as a component of smart health (Abbasi et al., 2014).

A summary of the result is presented in Table 1.

Table 1 Components of a smart health ecosystem for asthma patients

Publication type	**Author(s)**	**Components identified**	**Year of publication**	**Publisher**	**Title**
Conference	Al-Dowaihi et al.	Peak flow meter device, mobile phone, portal, internet, server, patients, healthcare practitioners	2013	IEEE	mBreath: Asthma Monitoring System on the Go
Conference	Thomson et al.	Patients, healthcare practitioners	2017	IEEE	Aspira: Employing A Serious Game in an Mhealth App to Improve Asthma Outcomes
Journal	Iyawa et al.	Patients, healthcare practitioners, healthcare institutions and organisations	2016	ScienceDirect	Digital Health Innovation Ecosystems: From Systematic Literature Review to Conceptual Framework
Journal	Rahmani et al.	Body area sensor network, internet-connected gateways, cloud and big data support	2018	ScienceDirect	Exploiting Smart E-Health Gateways at the Edge of Healthcare Internet-of-Things: A Fog Computing Approach
Conference	Suzuki et al.	Sensors, wearable technologies, processor, storage, hardware, software	2013	IEEE	Wearable Wireless Vital Monitoring Technology for Smart Health Care
Conference	Kassem et al.	Peak flow meter, mobile phones,	2013	IEEE	Asthma Care Apps
Conference	Yung-Cheng et al.	Electronic textiles, cloud computing	2013	IEEE	Smart-Clothes --- Prototyping of a Health Monitoring Platform
Conference	Uddin et al.	Mobile phone	2013	IEEE	SmartSpaghetti: Use of Smart Devices to Solve Health Care Problems
Journal	Abbasi et al.	Social media	2014	IEEE	Social Media Analytics for Smart Health
Journal	Solonas et al.	Electronic health, Mobile health, Privacy, Security and Professionals	2014	IEEE	Smart Health: A Context-Aware Health Paradigm within Smart Cities
Conference	Teixeira and Postolache	Wireless sensor network (sensor nodes, routers and gateways,	2014	IEEE	Wireless Sensor Network and Web based Information

		sensor node firmware, system software)			System for Asthma Trigger Factors Monitoring
Journal	Kwan et al.	Mobile devices, microcontroller and sensor circuit	2015	IEEE	Personal Lung Function Monitoring Devices for Asthma Patients
Conference	Meyer and Boll	Monitoring component, physical devices	2014	IEEE	Smart Health Systems for Personal Health Action Plans
Conference	Uwaoma and Mansingh	Mobile phones	2015	IEEE	Towards Real-time Monitoring and Detection of Asthma Symptoms on Resource-constraint Mobile Device
Conference	Sheng et al.	Bluetooth technology, wearable technology, Smartphone sensors	2015	IEEE	Fihuo: A Moblie Smart Health Service Platform
Conference	Siddiquee et al.	Internet of Things (IoT)	2016	IEEE	Smart Asthma Attack Prediction System Using Internet of Things
Conference	Wu et al.	Mobile application	2016	IEEE	A Smart Phone Application in Improving Healthy Lifestyles and Health Outcomes for School-age Children with Asthma
Conference	Ra et al.	Sensors, mobile phone, cloud web infrastructure, machine learning	2016	IEEE	AsthmaGuide: An Asthma Monitoring and Advice Ecosystem
Journal	Fuentes et al.	Internet of Things	2018	IEEE	Attribute-Based Credentials for Privacy-Aware Smart Health Services in IoT-Based Smart Cities
Conference	Kokalki et al.	Sensor, wearable device	2017	IEEE	Smart Health Band using IoT
Conference	Kumar et al.	Privacy, security	2018	IEEE	Security and privacy solution for I-RFID based smart infrastructure health monitoring
Journal	Zhang et al.	Privacy, security	2018	IEEE	Security and privacy in smart health: efficient policy-hiding attribute-based access control
Conference	Do et al.	Deep learning, forecasting	2016	Scopus	Big Data and mHealth Drive Asthma Self-Management
Journal	Kikidis et al.	Patients, healthcare practitioners	2016	Google Scholar	The Digital Asthma Patient: The History and Future of Inhaler

					Based Health Monitoring Devices
Journal	Sampri et al.	Google Trends	2016	ScienceDirect	Evaluating Google Trends as a Tool for Integrating the 'Smart Health' Concept in the Smart Cities' Governance in USA
Journal	Venkatesh et al.	Internet of Things	2018	IEEE	Modular and Personalized Smart Health Application Design in a Smart City Environment
Gray literature	Deloitte	m-health, mobile devices	2018	Google Search Engine	A Journey Towards Smart Health: The Impact of Digitalization on Patient Experience
Gray literature	Eramo	Smart inhalers, wearable technologies, mobile applications	2018	Google Search Engine	Three Ways Asthma Treatment is Getting Connected

Table 1 Components of a smart health ecosystem for asthma patients

DISCUSSION

The purpose of the chapter was to conduct a systematic literature review on smart health ecosystems for asthma patients. Specifically, the aims of this chapter were to explain what a smart health ecosystem for asthma patient is and to identify the components of a smart health ecosystem for asthma patients. The chapter also provides a conceptual framework for a smart health ecosystem for asthma patients (Figure 2). In total 28 studies were included in this systematic literature review, and to the best of the researchers' knowledge, this is the first time such a study is being conducted.

Some of the studies described the concept of *smart health ecosystem*. Based on the discussion in the literature and a combination of definitions provided by different authors, a *smart health ecosystem* for asthma patients can be defined as a set of intelligent devices able to monitor patients before, during and after an asthma attack, and send relevant information to health care practitioners in real time. These intelligent devices should be able to perform functions such as prediction (Ra et al., 2016; Do et al., 2016) and sensing (Suzuki et al., 2013; Kolkalki et al., 2017).

Components of a *smart health ecosystem* include human and non-human components. Human components consist of patients and healthcare practitioners (Al-Dowaihi et al., 2013; Thomson et al., 2017). Human components can also include healthcare institutions which are managed by healthcare stakeholders (Iyawa et al., 2016). The ecosystem does not exist and cannot function without the participation of a human component. The human component of the smart health ecosystem for asthma patients drive the non-human components.

Non-human components of a smart health ecosystem for asthma patients are technological in nature. They are categorized into two types: physical devices and applications. Physical devices may include peak flow meter devices, mobile phones, sensors, wearable technologies, processors, storage solutions, electronic textiles, microcontrollers, smartphone sensors and smart inhalers as indicated in Table 1.

The application component may include portals, the Internet, servers, body area sensor networks, Internet-connected gateways, cloud and big data support, cloud computing, social media, electronic health solutions, mobile health solutions, privacy and security solutions, wireless sensor networks, Bluetooth technology, IoT, mobile applications, machine learning, deep learning, forecasting, and Google Trends as indicated in Table 1. A conceptual framework of how these human and non-human components interact within a smart health ecosystem for asthma patients is presented in Figure 2 below.

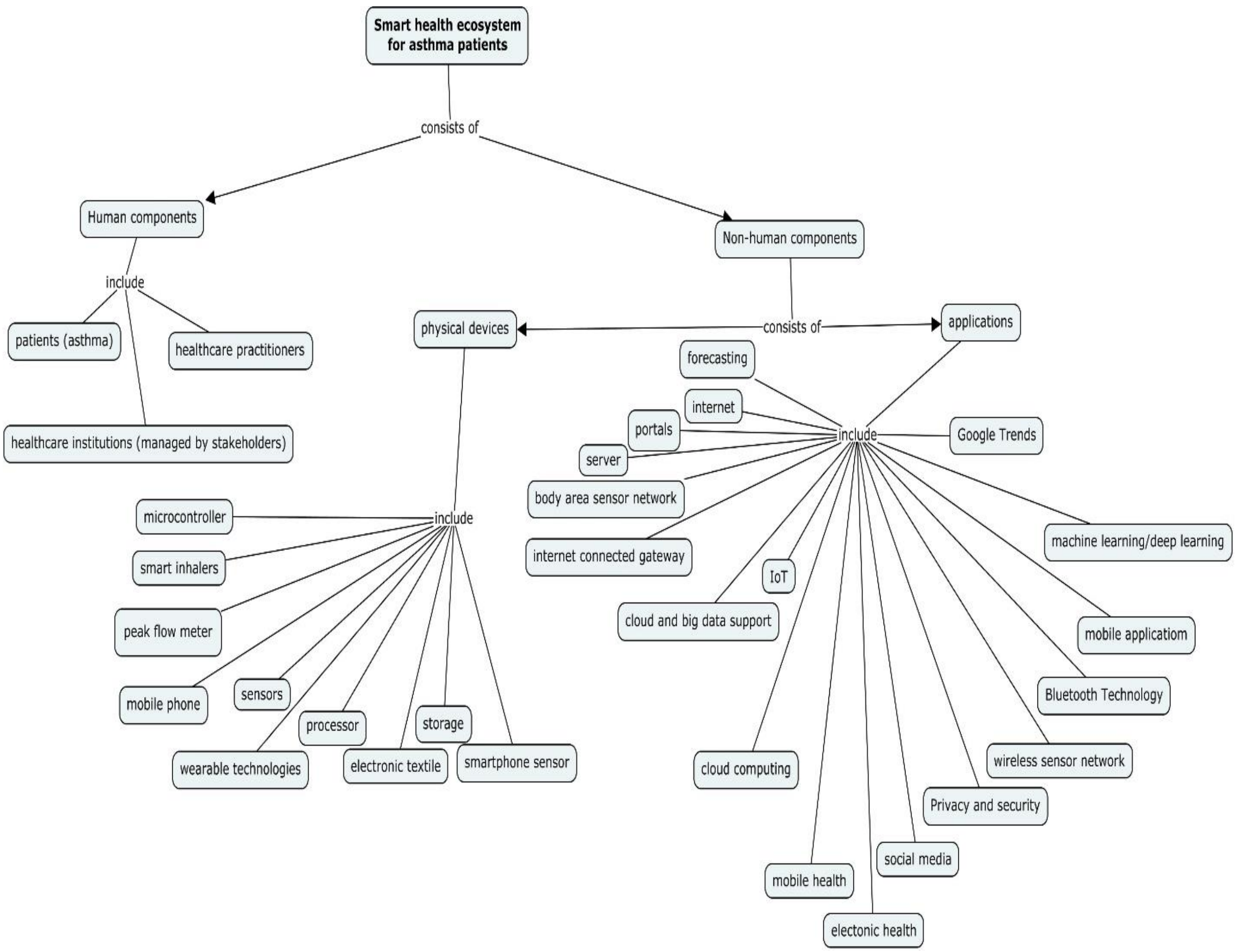

Figure 2 Conceptual framework for smart health ecosystem for asthma patients

Peak flow meter devices are necessary for determining the flow of air in the lungs (Al-Dowaihi et al., 2013), while smart inhalers are able to determine how a patient makes use of the inhaler (Eramo, 2018). The use of smart inhalers (Eramo, 2018) and smartphone sensors (Sheng et al., 2015) is usually facilitated through Bluetooth technology (Sheng et al., 2014). Wearable technologies, wireless sensor networks and sensors can facilitate a body area network to enable the monitoring of asthma patients (Teixeira and Postolache, 2014; Ra et al., 2016). Wireless communication is necessary to ensure the flow of information (Suzuki et al., 2013), which is supported by Bluetooth technology and the Internet. Sensors can be embedded in wearable technologies such as electronic textiles (Yung-Cheng et al., 2013; Kokalki et al., 2017). Microcontrollers such as Arduino devices can be used to facilitate monitoring of patients (Kwan et al., 2015). Fast processors and high storage systems such as cloud computing platforms are necessary in ensuring high-quality processing of patient data and storage. Data storage can likewise be processed more efficiently with big data which can breed other useful applications such as machine learning and deep learning (Do et al., 2016). Forecasting can be provided through social media analytics (Abbasi et al., 2014) and Google Trends. Mobile phones (Uddin et al., 2013; Uwaoma and Masingh, 2015; Deloitte, 2018) and mobile applications (Kassem et al., 2013; Wu et al., 2016), which are all part of mobile health, are necessary to facilitate deployment and ubiquity. Most of the mobile applications for asthma care are facilitated through the Internet and Internet connected gateways. Smartphone sensors can be used to gather relevant information about environmental information to alert both patients susceptible to potential asthma attacks and healthcare practitioners (Sheng et al., 2015). Portals and servers are also important in viewing patient information and providing services in the ecosystem. Social media can also play a role in ensuring the functionality of the ecosystem as patients and doctors can be linked on social media platforms to facilitate healthcare. IoT cannot be left out in a smart health ecosystem as they facilitate monitoring of patients through sensors and wearables (Fuentes et al., 2018; Siddiquee et al., 2016, Do et al., 2015). Privacy and security in the ecosystem cannot be left out as patients' data have to be protected (Zhang et al., 2018; Solonas et al., 2014).

CONCLUSION

The aim of this chapter to define a smart health ecosystem for asthma patients and describe its components was achieved by developing a conceptual framework. The findings from this study provide useful building blocks for the development of an effective smart health ecosystem for asthma patients by providing a clear set of requirements. It would be interesting to investigate how this ecosystem can be validated by both asthma patients and asthma healthcare providers in different contexts. This first academic study on smart health ecosystems has established the building blocks for future research in this area. Guidelines for implementing such an ecosystem was not provided, as such can be included in future research. For future work, researchers should endeavor to trial some of the technologies proposed as there were less publications in that area.

One major limitation with the study is the use of only three academic databases to search for relevant publications. This might have limited the number of papers that were used in this study. The reason for choosing these databases was because of their reputation for publishing excellent research on the subject. However, Google Scholar and Google Search Engine were used to identify other relevant papers the authors might have missed out. The inclusion and exclusion criteria might have also limited the type of papers which were included in this study. As such, relevant papers might have been excluded in the process. To decrease chances for bias, each paper reviewed was independently reviewed by two other reviewers. The findings were later collated and analyzed comprehensively.

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