Review Article

Use of Internet of Things for Chronic Disease Management: An Overview

Abstract

Most of the countries with elderly populations are currently facing with chronic diseases. In this regard, Internet of Things (IoT) technology offers promising tools for reducing the chronic disease burdens. Despite the presence of fruitful works on the use of IoT for chronic disease management in literature, these are rarely overviewed consistently. The present study provides an overview on the use of IoT for chronic disease management, followed by ranking different chronic diseases based on their priority for using IoT in the developing countries. For this purpose, a structural coding was used to provide a list of technologies adopted so far, and then latent Dirichlet allocation algorithm was applied to find major topics in literature. In order to rank chronic diseases based on their priority for using IoT, a list of common categories of chronic diseases was subjected to fuzzy analytic hierarchy process. The research findings include lists of IoT technologies for chronic disease management and the most-discussed chronic diseases. In addition, with the help of text mining, a total of 18 major topics were extracted from the relevant pieces of literature. The results indicated that the cardiovascular disease and to a slightly lesser extent, diabetes mellitus are of the highest priorities for using IoT in the context of developing countries.

Keywords: *Chronic disease in developing countries, chronic disease management, Internet of Things for chronic disease, Internet of Things for health care, latent Dirichlet allocation, smart health care*

Mehdi Dadkhah[1], Mohammad Mehraeen[1], Fariborz Rahimnia[1], Khalil Kimiafar[2]

[1]Department of Management, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, [2]Department of Medical Records and Health Information Technology, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran

Submitted: 08-Feb-2020 **Revised:** 30-Mar-2020 **Accepted:** 24-Apr-2020 **Published:** 24-May-2021

Introduction

Internet of Things (IoT) offers a wide range of solutions, which can be used to enhance the quality of health care at even lower cost,[1] thereby serving as a key enabler to sustain health-care delivery.[2] IoT refers to a network of interconnected smart things (e.g., sensors, smartphones, and RFID tags) that allow people and things to interact at virtually any time/anywhere to provide the desired services.[3-5] IoT contributes to effective and efficient treatment by revolutionizing the traditional health-care systems through providing a continuum of care and precise prognosis, sharing effective health strategies between various regions, checking patients' compliance with the treatment, offering effective and customized treatment planning, and getting insight from the collected information. IoT provides a more comprehensive approach to health care, especially for patients with chronic conditions.[6] The benefits of utilizing the IoT for chronic disease management highlight the need for developing the technology for this special application. This has been further reflected in the literature on chronic disease management. The rate of incidence of chronic diseases is increasing throughout the world, threatening the developing countries in particular.[7] According to the World Health Organization (WHO), the rate of chronic diseases and resultant fatalities in the low- and middle-income countries is anticipated to increase until 2030.[7,8] Abegunde *et al.* inspected a total of 23 low- and middle-income countries in 2005 and concluded that some 84 billion dollars of economics production will be lost during 2006–2015 if no action is taken against the chronic diseases in these countries.[9] Given the costs and fatalities incurred by chronic diseases, it is necessary to take action for decreasing the respective damages.[7] In the meantime, new technologies (e.g., IoT) can provide promising comprehensive solutions for enhancing health-care quality at even lower costs.[1,6]

How to cite this article: Dadkhah M, Mehraeen M, Rahimnia F, Kimiafar K. Use of internet of things for chronic disease management: An overview. J Med Sign Sens 2021;11:138-57.

Address for correspondence:
Prof. Mohammad Mehraeen, Department of Management, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran.
E-mail: m-lagzian@um.ac.ir

Access this article online

Website: www.jmssjournal.net

DOI: 10.4103/jmss.JMSS_13_20

Quick Response Code:

Despite the presence of a number of literature reviews on the use of IoT for improved health care in general[10,11] and the fact that a review on the relevant literature confirms the presence of efforts toward using the IoT for chronic disease management, compilation of the achievements of the research works focusing on the use of IoT for chronic disease management in a neat and integrated report is yet lacking. Describing different chronic diseases and technologies used for particular purposes so far, such an overview would help other researchers who are planning to work on the use of IoT for chronic disease management. Given the required time and budget for implementing IoT for chronic disease management, it is also necessary to prioritize different chronic diseases for using IoT in the developing countries.

The present article aims to not only compile an overview on the literature discussing the use of IoT for chronic disease management, but also prioritize chronic diseases for the use of IoT. Section 2 sets out the methodology adopted in the current study, while Section 3 describes the findings and Section 4 presents a discussion on the presented works and draws some conclusions.

Research Methodology

In order to provide an overview (mainly by using text mining) on literature discussing the use of IoT for chronic disease management, a number of articles on literature analysis and applications of IoT for chronic disease management were reviewed to determine the dimensions that help provide an overview on the available literature.[10,12-17] Finally, the present research questions (RQs) were developed based on the identified dimensions.

Research questions

The followings are the RQs investigated in this work:

RQ1. *Which technologies are engaged in the use of IoT for chronic disease management?*
RQ2. *What chronic diseases are most discussed?*
RQ3. *Which topics are usually appeared in the literature?*
RQ4. *How is the distribution of documents among the mentioned topics?*
RQ5. *Which chronic disease(s) has higher priority for using IoT?*

The following three methodologies were used to address the RQs: structural coding, latent Dirichlet allocation (LDA), and fuzzy analytic hierarchy process (FAHP). Indeed, structural coding was used to provide answers to RQ1, while RQ2 was addressed using quantitative analysis of textual data (quanteda), and LDA was devised to investigate RQ3 and RQ4. Finally, RQ5 was surveyed using FAHP. The required data for RQ1–4 will be collected by literature searching and RQ5 will be answered by the collected data from the survey.

Structural coding

In an attempt to identify technologies engaged in the use of IoT for chronic disease management, one should search for related pieces of literature followed by having them analyzed. This study uses the keywords Internet of things + chronic disease, IoT + chronic disease, and wireless sensor + chronic disease to find relevant literature. The search was done in the Google Scholar where most academic journals, books, and proceedings are indexed.[18] The term “*wireless sensor + chronic disease*” was used because most applications of wireless sensor network for chronic disease management have potentials for IoT implementation given that wireless sensor networks have been an important element of the IoT[19] and played a key role in the evolution of IoT.[20] The search process was done on February 18, 2019, without applying the publication year filter on the search results to cover the indexed contributions published until that date. The top 1000 search results for the first and second searched terms and the top 400 search results for the third searched term were analyzed as the next search results were seemingly irrelevant. Some search results were common between different key terms, especially the first and second ones (Although the IoT is the acronym for Internet of things, the searches for the two-term led to different results [at least in the order of appearance]. Hence, both of the key terms were searched for to enhance reliability.) Moreover, some literature reviews appearing in the search results were selected as those contained lists of cases where IoT was used.

Following the search strategy described herein, we ended up with a total of 161 contributions. As a supplementary source of information, the list of chronic diseases by the WHO (WHO, 2001 as cited in Patra *et al.*, 2007) was used as a checklist. All of the 161 papers were scanned to identify the chronic disease(s) discussed in each of them. In cases where the number of contributions discussing a particular chronic disease was turned out to be few or equal to zero, the Google Scholar was searched for the chronic disease along with the term “Internet of things.” Should such a search strategy failed to return acceptable number of results, the name of the chronic disease was further searched for in combination with the term “wireless sensor network” to cover as much of relevant studies as possible. The search process was stopped once the search results seemed irrelevant or an acceptable number of relevant studies were found. Although no upper limit was set for reviewing the search results, one to four relevant contributions were selected for each search to keep the number of considered contributions manageable in the terms of time and effort. For the chronic diseases for which the Google Scholar returned no result on the use of IoT, the main Google search engine was adopted to find relevant studies, if any. This auxiliary search step led to the identification of 25 more relevant contributions, increasing the total number of relevant contributions to 186 [Appendix 1 and Figure 1].

In this research, structural coding of the literature was utilized to identify the IoT technologies customized for chronic disease management. The structural coding provides a tool for quick identification of the specific part(s) of a text relating to a particular RQ. It is useful when encountering large datasets generated from semi-structured methods. For this purpose, one should begin with coding the questions and respective answers before consolidating and extracting the relevant data from the entire text. Indeed, structural coding undertakes data coding and categorization to enable identification of commonalities, differences, and relationships. Acting as an indexing system, it allows researchers to focus on relevant data to a specific analysis out of a large dataset.[21-26]

By using structural coding, different parts of each article relating to assistive technologies were identified and compiled for future coding and analysis. RQDA, a qualitative library for R software,[27,28] was utilized to simplify the coding task. In fact, the RQ1 could be addressed by merely reading the selected articles rather than going through structural coding. However, considering the uncertainty resulted from failure to clearly indicate the used technology in the considered articles, a coding strategy was adopted to simplify this process.

Making a literature review, Guest *et al.* introduced techniques for enhancing the validity and reliability in qualitative research.[21] Some of these techniques were used in this work, including team-based research instrument design, team training for data collection, real-time data monitoring, intercoder agreement (coding the data by two researchers and comparing the results), and external review (having the data and related interpretations reviewed by an external researcher).

Quanteda technique

Various computer-assisted tools have been developed for qualitative data analysis.[29] In the current work, the Quanteda, an R package for quantitative analysis of text data,[30,31] was used to identify the most-discussed chronic diseases. To do that, the list of chronic diseases released by the WHO was used as a reference.[32] In the first step, contents of all of the 186 contributions were fed, in plain text format, to the R software followed by searching for the chronic diseases on the WHO list by using the tutorials[31,33] to identify the articles discussing on each disease (we used the available codes in tutorials with some editions). An essay containing 60 words before and 60 words after the reference to the chronic disease was extracted for each contribution. The results were manually inspected to ensure that the reference was made in the scientific content of the contribution rather than the meta data such as researchers' affiliations, title of conference, journal names, and citations. Without such strategy, affiliation of an author working at a cancer center, for example, would mistakenly recognize the contribution as the one discussing on cancer.

The method used for finding the most-discussed chronic diseases came with three important flaws. First, the contributions that even briefly introduced a particular chronic disease would be recognized as the ones discussing on that chronic disease. Second, there might be cases where the solution provided in a particular contribution was of help for more than one chronic disease, but the authors failed to refer all chronic diseases which could be covered by the solution. And third, the WHO-provided list of chronic diseases is not inclusive of all chronic diseases in each category, but rather uses an "other diseases" item on the list of each category. Investigating the three flaws, it was found that their impacts on the results are not significant because of three main reasons: (1) if a chronic disease was really noteworthy, the authors would indicate its name throughout their papers; (2) the brief introductions to chronic diseases were generally too rare and limited to place a chronic disease on the most-discussed list (however, the results were manually inspected to avoid such problems); and (3) the fact that the instances of the main categories were searched for implies that the instances of possible diseases that were not listed by the WHO were ignored; this may be interpreted as a limitation of the present research, but one may reason that the WHO would list such chronic diseases if those were significant. Nevertheless, the missed most-discussed diseases, if any, might appear in the results of LDA.

Latent Dirichlet allocation

An objective of the present study has been to evaluate major topics in the selected pieces of literature (RQ3 and RQ4). The so-called LDA was applied for this purpose. Before this algorithm could be implemented, the collected data must be prepared by having them converted to plain text, to facilitate cleanup and other processes on the data, checking the converted text files for a list of stop words, transforming all letters to lower case, and removing punctuations, numbers, stem words, and special characters (e.g.-, @).[34-36] In the relevant research works, the prepared data for LDA algorithm are usually referred to as "clean data." Interested readers may refer to Sherman's book for more information.[37]

Introduced by Blei *et al.*, LDA provides a probabilistic generative model for text collection. The main idea behind LDA is the assumption that each essay is a mixture of latent topics, with each topic being defined as a particular distribution of related words.[38] The LDA has been widely used for topic modeling and literature analysis.[39-42] In this article, LDA was utilized to identify major topics in the selected contributions [Figure 1] using a statistical tool called R Software.[28] In this regard, available tutorials about applying LDA by using R and analyze data have been used (we used available codes in tutorials with some editions).[34,35,43,44] For this purpose, word clouds were extracted based on the selected pieces of literature, optimal

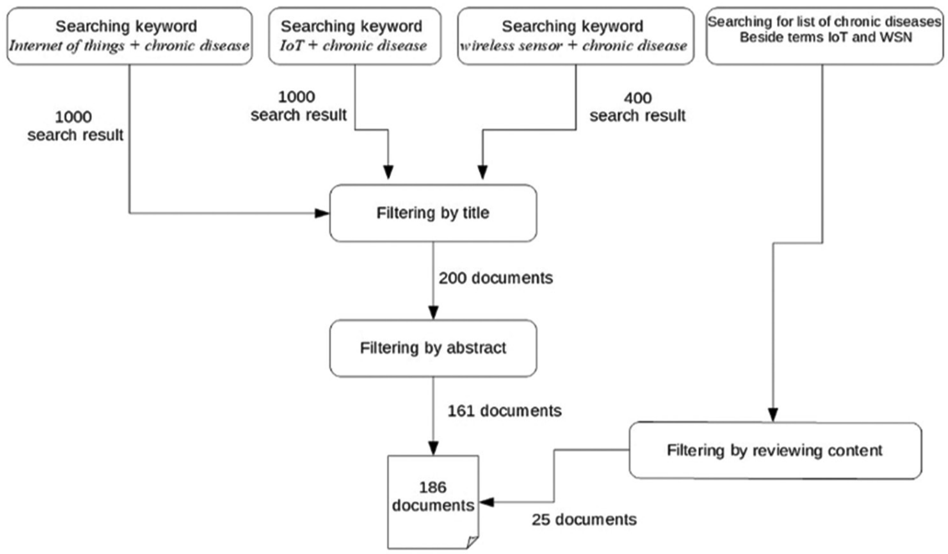

Figure 1: The search strategy adopted in this study

number of topics were identified, top ten keywords for each topic were identified, and distribution of the documents among different topics was evaluated.

Fuzzy analytic hierarchy process for prioritizing chronic diseases for Internet of Things

In order to prioritize the chronic diseases based on their priority for using IoT (RQ45), FAHP was used. AHP, introduced by Thomas Saaty, works by weighting a list of alternatives based on selected criteria.[45-47] The uncertainty associated with the decision environments justifies the use of FAHP to rank the chronic diseases.[48,49] Chang developed a FAHP as an extent analysis method,[50] which later on became the most popular FAHP technique and was frequently used for pair-wise comparisons, as is the case in the present work.[51]

In the current study, the most-discussed categories of chronic diseases in the developing countries were used as the alternatives for the FAHP model. The categories were identified based on a review on the studies discussing chronic diseases in the developing countries. These included malignant neoplasms, diabetes mellitus, cardiovascular diseases, and respiratory disorders.[7,9,32,52,53] Here, we used the categories of chronic diseases rather than particular diseases to keep the number of alternatives reasonable. The criteria for a FAHP model can be defined by researchers or based on the relevant literature. As mentioned in the *Introduction section*, chronic diseases incur both costs and fatalities, thus "cost reduction" and "death prevention" were herein selected as the criteria to weight different categories of chronic diseases for using IoT. Figure 2 shows AHP model for prioritizing different categories of chronic diseases for using IoT.

To ensure consistency of the result, various consistency indexes and approaches exist.[54] In this research, the method

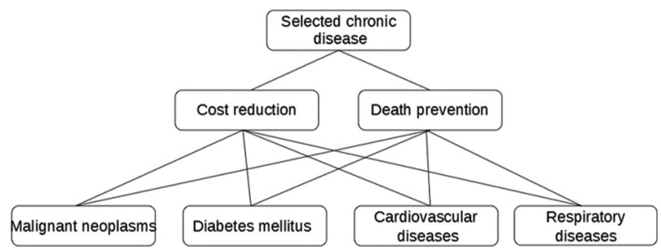

Figure 2: Fuzzy analytic hierarchy process model for ranking different categories of chronic diseases based on their priority for using Internet of Things

proposed by Gogus and Boucher was used. According to this method, a matrix is recognized as consistent if the value of two consistency rates (CR), namely CR^m and CR^g, are equal to or lower than 0.1 for each comparison matrix.[55]

Results

This section presents the results obtained upon applying each of the used methods. We distinguish between findings of different methods to better understand the results, but this does not mean that these findings are independent of one another. The entire set of findings provides an overview on the literature.

Engaged technologies and most-discussed chronic diseases

Based on the structural coding task and related analysis, IoT technology and sensors, big data, cloud computing, fog computing, robotics (Robots can also be considered as IoT-enabled devices), web-based technologies, blockchain, and semantic technology were identified as the main assistive technologies for IoT-based chronic disease management. Different cases may use a different combination of these technologies to provide desired services. IoT-equipped sensors have been used to gather data from the surrounding environment or measure patient's vital parameters. These could be further developed to process such data and take actions autonomously. For example, Li *et al.* proposed a pervasive monitoring system for measuring physical signs of the patient, for example, blood pressure, electrocardiogram, SpO_2, and heart rate, and his/her location and send them to a remote server.[13] Continually sensing the subject and generating data, an IoT device produces huge amounts of data (i.e., big data) that can be processed to provide valuable pieces of information for disease detection or development of smarter solutions. Gachet Páez *et al.* discussed the use of big data and IoT for chronic disease management.[56]

Cloud computing provides portability for the use of IoT for patient monitoring. It stores the data collected through IoT devices on the cloud where the required computation can be done.[57] In their study, Sinnapolu and Alawneh developed an iOS application for heart rate monitoring by using a wearable sensor. In emergencies (i.e., critical conditions occurring to the patient), the application could route the nearby hospitals for the drive or take other actions such as pulling over for assistance.[16] In cases where real-time data analysis is required and common delays with cloud computing cannot be tolerated, fog computing can be of help. Cisco developed the fog or edge computing as an extension to the cloud computing. Here, the fog refers to an intermediator between the user and the cloud, which acts to reduce the latency by performing real-time data analysis rather than sending such huge amounts of data to the cloud for processing.[57]

Blockchain refers to a network of publicly distributed systems that transmit records of transactions in a way that cannot be falsified after the event. It uses an asymmetric encryption method with different keys for encrypting and decrypting a message or transaction.[58] Saravanan *et al.* developed a secure mobile device for diabetes monitoring, wherein the blockchain was used to ensure the security of and trusted access to the collected data.[59]

As of present, the semantic technology is usually used for inference purposes. It creates an ontology model to define relationships between different concepts. An ontology model provides a framework for describing the knowledge about a particular subject by considering different concepts and their relations.[60,61] For example, Jara *et al.* presented a system for drug identification and delivery using the ontology and IoT, wherein the ontology described the drug concepts and patient's information, while the IoT helped identify drugs using radio-frequency identification (RFID), near-field communication (NFC), or similar technologies.[62]

The identified technologies can be used in general patient monitoring systems not only systems for chronic diseases management. In other words, the use of IoT for chronic disease management describes a special case of the use of IoT in the scope of general health care, and this is why there are common technologies that can be applied in both contexts.

Based on the analysis results and the existing studies,[57,63] Figure 3 shows the interaction among several technologies adopted for smart chronic disease management, including IoT, big data, cloud computing, and fog computing, for a case where all of the four technologies were engaged. Sensors and IoT devices gather data from patients. Fog computing does real-time analysis on the data, and cloud computing serves as the main storage for the collected and processed data. In a hospital or a research center, analytical tools and methods can be used to recognize patterns in the data or develop new applications. Doctors and professionals in the hospital can monitor patients remotely and assist them in emergencies. This model is not exclusive to chronic disease management, but rather general IoT-based patient monitoring systems may utilize the same interaction schemes among related technologies.

Development of each of the mentioned technologies (or any combination of them) to provide new IoT applications or improve the available solutions for chronic disease management provides topics for future research in this domain. Some researchers elaborated on the security and privacy challenges associated with the use of IoT in health-care domain.[11,64] In this respect, blockchain has been recognized as a promising technology for ensuring the security and privacy of the data collected through IoT for health-care applications.[65] Further development of blockchain into smart chronic disease management and health-care systems can be investigated in future research works.

Produced by Quanteda and R package, Table 1 shows statistical information about the contributions discussing each chronic disease. The first column (Column A) in this table lists the chronic diseases. The second column indicates the keywords searched for each chronic disease. The third column (number of studies) refers to the number of contributions wherein the respective key term has been mentioned at least once. An attempt was made to set the key terms in such a way to have as wide range of results as possible, followed by manual inspection of the results.

The fundamental question to address in this step is whether a higher frequency of reference to a particular chronic disease in the literature can recognize the diseases as a most-discussed one? To answer this question, diabetes and cardiovascular diseases, as the two most-cited chronic diseases, were manually investigated; indeed, these were candidates for most-discussed chronic diseases, with the results confirming that diabetes and cardiovascular diseases were the most-discussed chronic diseases in the studied literature.

Based on related analysis, there were studies discussing the actual or potential applications of IoT for supporting the patients engaged with chronic disease such as cancer, diabetes, depression, dementia, cardiovascular diseases, and asthma. The level of support varied from simple data collection via an IoT-enabled device to highly sophisticated

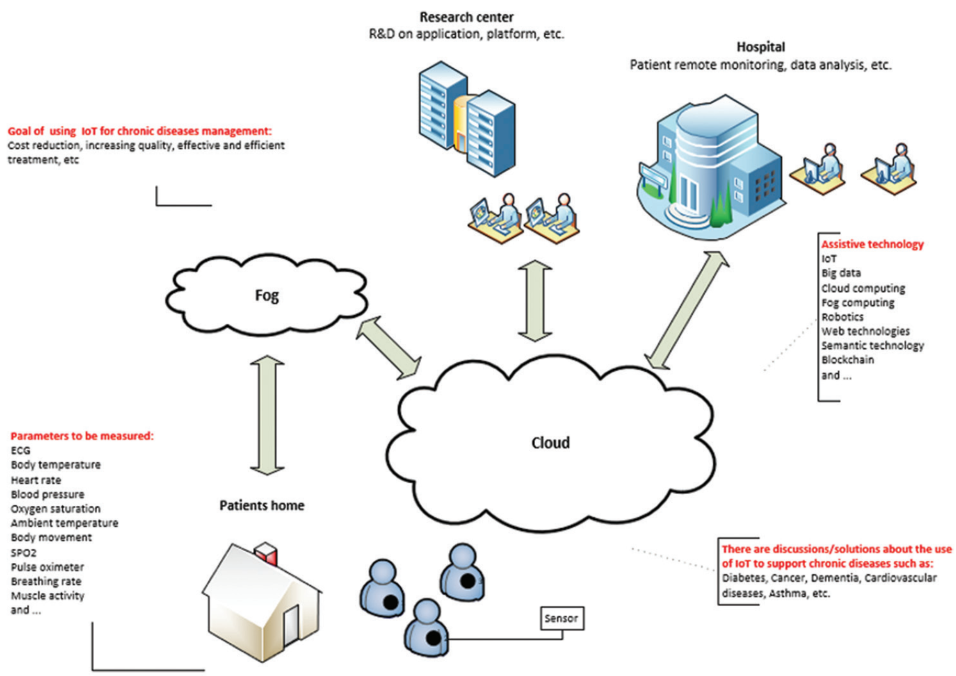

Figure 3: A brief picture of the literature on the use of Internet of Things for chronic disease management in terms of patient monitoring (some parts adapted[1,6,10,57,63])

levels. In addition, some of the studies provided no more than brief explanations on the possibility of using IoT or wireless sensors for a specific chronic disease rather than presenting comprehensive solutions. Future research works may focus on the formulation of IoT for the management of the chronic diseases for which IoT has either not been applied yet or been applied partly or at lower levels of maturity. In their work, Dadkhah *et al.* identified different stages of IoT development and indicated possible contributions of health-care professionals to the IoT body of knowledge.[66]

IoT-enabled devices usually use sensors to measure one or more specific parameters of the patient's body to monitor a particular chronic disease. Figure 3 demonstrates some of these parameters based on the work by de Morais and AdeAquino.[10] With the advance of medical science, new parameters may become necessary for monitoring particular chronic diseases, necessitating special sensors and IoT devices for measuring them. Accordingly, future research work may also focus on the development of new sensors.

As discussed in the Introduction section, IoT promotes health-care quality at even lower cost.[1] It can revolutionize the health care by providing effective and efficient treatment and new capabilities, especially for chronic disease management.[6] Before adopting IoT, managers need to delineate their goal and then decide about the specific IoT application(s) that may render helpful regarding the considered chronic disease and the ultimate goal. Customizing IoT strategies for various countries can be undertaken in future works.

The content and structure of this section and Figure 3 were adopted from other research works.[10,11]

Major topics in the literature and their distribution

As mentioned in Section 3, findings of the present section are based on text mining on clean data.[34-36,43,44] Figure 4 shows the word clouds extracted from the literature. As shown in this figure, patient, data, system, sensor, use, health, technology, and monitor were most frequently mentioned in the considered contributions. One may combine these keywords into a phrase: patient monitoring using different sensors and gathering related data. These keywords represent the main concepts on which the literature about the use of IoT for chronic disease management elaborate. The size of each keyword in Figure 4 represents its frequency of appearance.

For LDA analysis, one must begin with defining the number of topics to be extracted. In other words, LDA cannot calculate the optimum number of topics by itself and rather the user must set the number of topics as an input parameter. Different studies have presented various methods for determining the optimum number of topics for a LDA analysis.[67-70] Nikita Moor designed a library for R package: "ldatuning;" this library could be devised to draw graphs based on the available data and help researcher find the optimal number of topics for LDA analysis.[43,71] Accordingly, she used four metrics, namely Arun2010, CaoJuan2009, Deveaud2014, and Griffiths2004. Based on the output graphs of the mentioned library, researchers should find extremums, i.e., to find a range of topics for which Arun2010 and CaoJuan2009 are minimized, while Deveaud2014 and Griffiths2004 are maximized.[43] In

Table 1: Statistical information about the contributions discussing different chronic diseases

n	Chronic diseases*	Searched keywords	Number of studies which mentioned to a chronic disease
1	Nutritional deficiencies	Nutrition, malnutrition Iodine Vitamin Anaemia	Malnutrition=1
2	Malignant neoplasms	Neoplasms Cancer Lymphomas Myeloma Leukaemia	Cancer=23
3	Diabetes mellitus	Diabetes	Diabetes=83
4	Endocrine disorders	Endocrine	Endocrine=0
5	Neuro-psychiatric conditions	Neuro Psychiatric Depression Bipolar Epilepsy Alcohol Dementia Parkinson Sclerosis Drug use Post-traumatic stress Obsessive Panic Sleep disorder Migraine Retardation	Psychiatric=3 Depression=23 Bipolar=4 Epilepsy=10 Alcohol=11 Dementia=22 Parkinson=8 Sclerosis=4 Obsessive=0 Panic=1 Sleep disorder=5
6	Sense organ diseases	Sense organ glaucoma Cataracts Presbyopia Deafness	Glaucoma=4
7	Cardiovascular diseases	Cardiovascular Rheumatic Hypertension Ischaemic Cerebrovascular Inflammatory heart	Cardiovascular=47 Rheumatic=1 Rheumatism=1 Hypertension=37 Ischaemic=1 Cerebrovascular=5
8	Respiratory diseases	Chronic obstructive pulmonary disease Asthma	Chronic obstructive pulmonary disease=18 Asthma=24
9	Digestive diseases	Digestive diseases Peptic ulcer Cirrhosis of the liver Appendicitis	All equal to zero
10	Genitourinary diseases	Genitourinary Nephritis Nephrosis prostatic hypertrophy	Nephritis=2 Nephrosis=1
11	Skin diseases	Skin disease	Skin disease=2
12	Musculo-skeletal diseases	Musculo diseases Skeletal diseases Arthritis Osteoarthritis Gout Low back pain	Arthritis=13 Osteoarthritis=4 Gout=1

Contd...

Table 1: Contd...

n	Chronic diseases*	Searched keywords	Number of studies which mentioned to a chronic disease
13	Congenital anomalies	Congenital anomalies Abdominal wall defect Anencephaly Anorectal atresia Cleft lip Cleft palate Oesophageal atresia Renal agenesis Down syndrome Congenital heart anomalies Spina bifida	Spina bifida=1
14	Oral conditions	Dental caries Periodontal disease Edentulism	Periodontal disease=1

*This column has been adapted[32]

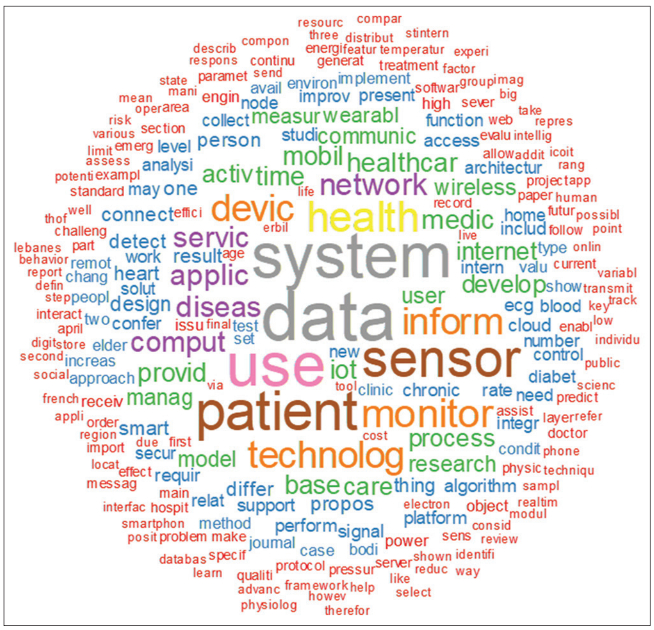

Figure 4: Word clouds extracted from the literature

the present data, similar graphs were developed for the clean data [Figure 5] and indicated that optimum results can be achieved in the range of 18 till 22 topics. In the current study, the number of topics was set to 18.

Providing the LDA algorithm with the optimum number of topics and applying Gibbs method,[72] the LDA algorithm returns top ten keywords for each topic (based on our used code) so that the user can label them.[73,74] Table 2 illustrates the topics with the corresponding keywords. In order to label each topic, the keywords corresponding to each topic were searched in the main Google search engine and Google Scholar, while there were cases where the data and related literature (the 186 selected contributions) were used to choose a label for a topic. In cases where the main Google search engine and Google Scholar were utilized, some of the labels were inspired by some studies.[75-77]

Table 2 shows the labels assigned to each topic. As shown in this table, some topics were broader than the others and *vice versa*. Each contribution might include multiple topics. Figure 6 illustrates the distribution of the contributions among different topics on a scatter plot. As shown in this figure and Table 2, the broader topics (e.g., topics 1 and 17) were discussed in more contributions (i.e., corresponding to higher gamma value). Data collection in IoT (topic 17) was the most widely covered topic; this makes sense because most of the discussions on the use of IoT for chronic diseases are kind of data-collecting process using sensors and devices.

Prioritization of chronic diseases for the use of Internet of Things

Prioritization of chronic diseases for the use of IoT was done by performing a survey among experts of chronic disease management. The questionnaire was made up of three questions about ranking criteria and alternatives for each criterion. In order to prepare the participants for the survey, they were provided with adequate deals of information about the research goal, IoT, and categories of chronic diseases. Ultimately, out of the distributed and collected questionnaires, six ones were filled validly. According to consultations with analytic hierarchy process (AHP) experts and based on available literature,[78] this number of forms was found to be adequate for further analysis. Applying the CR proposed by Gogus and Boucher, the participant was asked to revise his/her answer if the rate exceeded 0.1. Based on the experts' opinions and the method presented in methodology section, different criteria and diseases were ranked, as tabulated in Tables 3-6.

Results of the current study indicated that fatality prevention has higher priority over cost reduction so that managers must base their decisions about the use of IoT for chronic disease management on the fatality prevention rather than cost reduction. However, considering either of cost reduction or fatality prevention as a criterion, cardiovascular diseases and diabetes mellitus were found

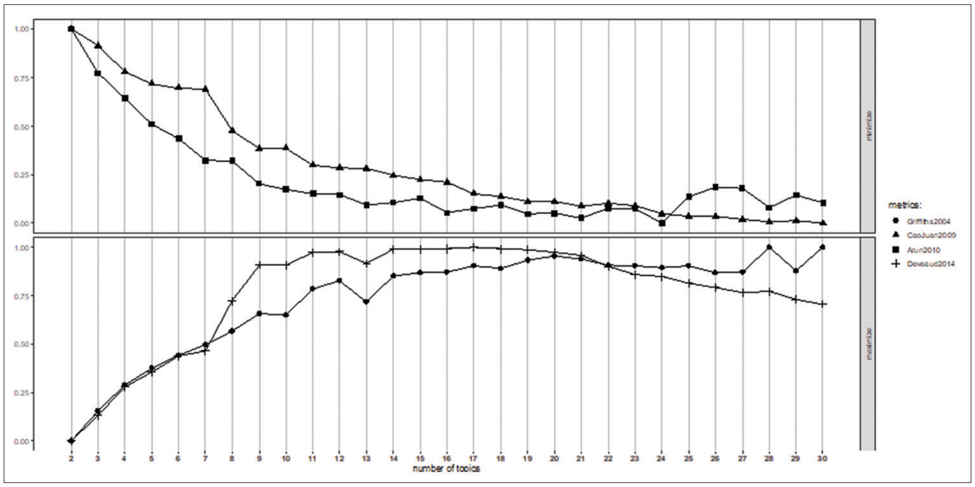

Figure 5: Finding optimal number of topics for the present work

Table 2: Major topics and corresponding labels

n	Keywords*	Topic label
1	Health, healthcar, system, servic, patient, diseas, smart, medic, data, cloud	Smart healthcare services
2	Secur, energi, cloud, IoT, effici, network, healthcar, comput, architectur, communic	Secure and energy-efficient healthcare
3	Patient, health, care, diseas, chronic, technolog, medic, clinic, treatment, healthcar	Medical treatment for chronic diseases
4	Model, predict, diseas, data, algorithm, use, accuraci, analysi, fuzzi, classif, factor	Modeling and predicting chronic diseases
5	Sensor, measur, asthma, power, wearabl, patch, monitor, environment, sens, signal	Asthma management
6	Inform, April, region, network, confer, technolog, Erbil, French, Lebanes, Icoit	Uncleaned meta data in the dataset such as affiliation, etc.
7	Iot, diseas, ontolog, data, diagnosi, algorithm, thing, internet, model, comput	Semantic IoT data modeling for chronic diseases management
8	Medic, model, iomt, design, cyberphys, garden, age, cps, perspect, concern, selfcar	No label
9	RFID, tag, drug, present, solut, patient, internet, integr, care, clinic	Drug delivery and management using IoT
10	Patient, heart, monitor, rate, pressur, blood, failur, diseas, system, doctor	Heart and blood pressure monitoring
11	Elder, activ, home, peopl, live, servic, aal, assist, sensor, smart	Older people assistant living
12	ECG, signal, monitor, wireless, sensor, node, network, system, patient, transmiss	ECG monitoring system
13	Diabet, mobil, patient, glucos, manag, blood, type, insulin, health, system	Diabetes management using IoT
14	Diseas, wearabl, parkinson, gait, sensor, assess, movement, acceleromet, activ, patient	Parkinson management using IoT
15	Compress, seizur, epilepsi, comput, sens, sampl, mcc, servic, visiot, cloud	Epilepsy management using IoT
16	Iot, wearabl, internet, thing, devic, data, avail, privaci, consum, track	Privacy concerns in wearable devices
17	Data, use, system, sensor, devic, inform, applic, technolog, process, provid	Data collection and processing in IoT
18	Analyt, data, iot, retriev, comput, survey, subject, storag, distribut, big	Data analytic in IoT

*Words are incomplete due to stemming process in the data-cleaning task. IoT – Internet of Things

Table 3: Weight of each criterion

Criteria	Weight	Rank
Cost reduction	0.211	2
Death prevention	0.789	1

to be of higher priority than the other diseases such as respiratory diseases or malignant neoplasms. This opinion holds equally whether fatality prevention, cost reduction, or a combination of both is selected as the criterion.

Discussion and Conclusion

The literature on the use of IoT for chronic disease management was overviewed. The main technologies engaged in the IoT-based chronic disease management were discussed, major topics in the literature were presented, and chronic diseases were prioritized for using the IoT.

Based on the results of LDA analysis, the most-discussed topics in the literature were identified [Figure 6]. In Figure 6, the dots show contributions of articles on respective topics, with the dots with higher values of gamma showing the domination of the respective topic in the literature. Represented by dots of the highest gamma value, topic 17 (data collection in IoT) is the dominant topic in the literature, possibly because of its broadness given that most applications of IoT in chronic disease management represent special cases of a data collection using sensors and devices. Relatively similar results were found for other broad topics, such as smart health-care services. Some topics exhibited low values of gamma

Table 4: Ranking of the chronic diseases based on their priority for using Internet of Things by considering cost reduction as a criterion

Chronic disease category	Weight	Rank
Malignant neoplasms	0.000	3
Diabetes mellitus	0.303	2
Cardiovascular diseases	0.697	1
Respiratory diseases	0.000	3

Table 5: Ranking of the chronic diseases based on their priority for using Internet of Things by considering fatality prevention as a criterion

Chronic disease category	Weight	Rank
Malignant neoplasms	0.000	3
Diabetes mellitus	0.363	2
Cardiovascular diseases	0.637	1
Respiratory diseases	0.000	3

Table 6: Overall ranking of chronic diseases based on their priority for using Internet of Things

Chronic disease category	Weight	Rank
Malignant neoplasms	0.00000	3
Diabetes mellitus	0.35034	2
Cardiovascular diseases	0.64966	1
Respiratory diseases	0.0000	3

(e.g., epilepsy management using IoT and semantic IoT data modeling), indicating limited extent of studies on these topics. Topics 10 and 12 discuss the application of IoT in a similar domain, however these topics are different.

Based on the experts' opinion, cardiovascular diseases followed by diabetes mellitus were of the highest priorities for using IoT in developing countries. The reason might be the inherent capabilities of IoT for the treatment of these diseases rather than malignant neoplasms and respiratory disorders. Moreover, knowing the significant contribution of life style into the management of cardiovascular diseases and diabetes mellitus, IoT device works well for monitoring the patient's life style. Considering Table 1, a lot of research works, among the selected pieces of literature, have focused on cardiovascular diseases and diabetes mellitus. For the cardiovascular diseases, this is understandable based on the result of LDA analysis because topic 10 and 12 are related to the use of IoT for cardiovascular diseases. However, when it comes to diabetes mellitus, only one topic (i.e., diabetes management) is directly related to the use of IoT for diabetes mellitus. Moreover, Figure 6 shows that the number of contributions discussing this topic is moderate. Accordingly, it seems that researchers have well understood the potentials of IoT for cardiovascular diseases and to a lesser extent, diabetes mellitus in terms of cost reduction and fatality prevention, encouraging them to do more research works on these two diseases (not only in the developing countries, but around

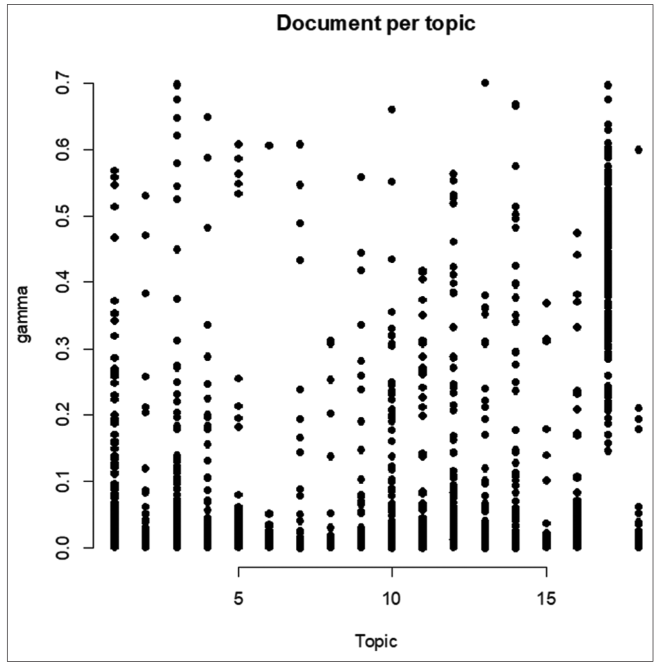

Figure 6: Distribution of contributions among different topics

the globe). Figure 6 further indicates that the contributions on the use of IoT for respiratory disorders are limited, with no contribution found on the malignant neoplasms. Nevertheless, still future research on the use of IoT for cardiovascular diseases and diabetes is necessary to formulate more comprehensive solutions while improving the existing ones.

Beside the research on cardiovascular diseases and diabetes mellitus, scientists are hereby encouraged to work on such relatively untouched applications of IoT as those for Parkinson management, Alzheimer management, epilepsy management, and also respiratory disorders.

Topic 2 and topic 16 discuss the security and privacy of IoT usage for chronic disease management. In literature, there is research which state that security of IoT is an important concern.[42,79,80]

This work was supposed to focus on the use of IoT for chronic disease management in developing countries. Although the search strategy did not reflect such an attitude, the presented rankings were based on that. Future research works may consider the developed countries to prioritize the chronic diseases in such countries and delineate the most significant criteria.

Despite the current study which considered the chronic diseases in general, future research works may focus on a specific category of chronic diseases by introducing related sensors and corresponding platform(s), current status of research, and guidelines for future research.

This research presented multiviews to the existing literature on IoT for chronic disease management through the following three methodologies: structural coding, LDA, and FAHP.

This was done by identifying the technologies engaged in IoT-based chronic disease management, most-discussed chronic diseases, major topics in the literature, and priority of chronic diseases in the developing countries.

This research suffers from a number of limitations. There were chances of inaccurately labeled topics in the LDA. The FAHP was based on the opinions of selected experts, and other experts may have different opinions. According to Figure 1, out of the 2400 contributions in which abstracts were scanned, only 186 articles were selected for further analysis. Later in the structural coding process, some of the selected contributions were recognized as irrelevant (upon analyzing their full texts) and hence excluded. However, the LDA and Quenteda library were applied on the entire set of the 186 selected contributions, i.e., these latter two techniques were applied on the results of the search strategy rather than the filtered data via structural coding. Some of the processes applied in this research were automatic or semi-automatic, making the susceptible to error, although the error was found to impose only insignificant impacts on the final results. Finally, the list of chronic diseases considered in this study is not comprehensive, but rather signifies the most-discussed diseases instead. Moreover, assistive technologies were identified based on the selected pieces of literature only, leaving the chances of the presence of other technologies in other studies.

For future read, interested readers are encouraged to read review articles elaborating on the use of IoT in the health-care domain.[10,11,81]

R Packages

The below R packages have been used in the current study:
- "tm"[82,83]
- "SnowballC"[84]
- "wordcloud"[85]
- "RColorBrewer"[86]
- "readxl"[87]
- "ldatuning"[88]
- "topicmodels"[89]
- "tidytext"[90]
- "ggplot2"[91]
- "dplyr"[92]
- "readtext"[93]
- "quanteda"[30]
- "summarytools"[94]

Acknowledgement

It is our pleasure to acknowledge researchers who helped and advised us during this research:

1. Prof. Robert M Davison, City University of Hong Kong
2. Prof. Roger Watson, Faculty of Health Sciences , University of Hull, Hull, HU6 7RX, UK
3. Mrs. Rozann W. Saaty, Creative Decisions Foundation, Pittsburgh, PA 15213
4. Nikita Murzintcev, Ph.D., IGSNRR, CAS, China
5. Dr. Sylvain KUBLER: Associate Professor at the Research Center for Automatic Control of Nancy (UMR 7039) in the Université de Lorraine (France)
6. Dr. Stephen Bales, PhD. Texas A&M University Libraries, USA
7. Dr. Sérgio Moro: Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR-IUL, Lisboa, Portugal
8. All of other expert colleagues who responded to our questionnaire or advised us.

Financial support and sponsorship

None.

Conflicts of interest

There are no conflicts of interest.

References

1. Couturier J, Sola D, Borioli GS, Raiciu C. How can the internet of things help to overcome current healthcare challenges. Digiworld Econ J 2012;87:67-81.
2. Turcu CE, Turcu CO. Internet of things as key enabler for sustainable healthcare delivery. Procedia Soc Behav Sci 2013;73:251-6.
3. Giusto D, Iera A, Morabito G, Atzori L. The Internet of Things: 20th Tyrrhenian Workshop on Digital Communications. New York: Springer; 2010. Available from: https://books.google.nl/books?id=vUpiSRc0b7AC. [Last accessed on 2020 May 03].
4. Guillemin P, Friess P. Internet of Things Strategic Research Roadmap. Cluster of European Research Projects on the Internet of Things. IERC-European Research Cluster on the Internet of Things; 2009. p. 1-50.
5. Vermesan O, Friess P, Guillemin P, Sundmaeker H, Eisenhauer M, Moessner K, *et al*. Internet of Things Strategic Research and Innovation Agenda. IERC-European Research Cluster on the Internet of Thing; 2014.
6. Chou D. What Can IoT do for Healthcare?; 2016. Available form: https://www.cio.com/article/3117385/internet-of-things/what-can-iot-do-for-healthcare.html. [Last accessed on 2019 Jan 02].
7. Nugent R. Chronic diseases in developing countries: Health and economic burdens. Ann N Y Acad Sci 2008;1136:70-9.
8. Adeyi O, Smith O, Robles S. Public Policy and the Challenge of Chronic Noncommunicable Diseases. Washington, DC: The International Bank for Reconstruction and Development/The World Bank; 2007.
9. Abegunde DO, Mathers CD, Adam T, Ortegon M, Strong K. The burden and costs of chronic diseases in low-income and middle-income countries. Lancet 2007;370:1929-38.
10. de Morais Barroca Filho I, de Aquino Junior GS. IoT-based healthcare applications: A review. In: Gervasi O, Murgante B, Misra S, Gervasi O, Murgante B, Misra S, Borruso G, Torre CM, Rocha AMAC, *et al*., editors. Computational Science and Its Applications – ICCSA 2017. Switzerland: Springer International Publishing; 2017. p. 47-62.
11. Islam SM, Kwak D, Kabir MH, Hossain M, Kwak K. The internet of things for health care: A comprehensive survey. IEEE Access 2015;3:678-708.
12. Kim SH, Chung K. Emergency situation monitoring service using context motion tracking of chronic disease patients. Cluster Comput

2015;18:747-59.

13. Li C, Hu X, Zhang L. The IoT-based heart disease monitoring system for pervasive healthcare service. Procedia Computer Sci 2017;112:2328-34.
14. Liberatore MJ, Nydick RL. The analytic hierarchy process in medical and health care decision making: A literature review. Eur J Oper Res 2008;189:194-207.
15. Panagiotou C, Antonopoulos C, Keramidas G, Voros N, Hübner M. IoT in ambient assistant living environments: A view from Europe. In: Components and Services for IoT Platforms. Switzerland: Springer; 2017. p. 281-98.
16. Sinnapolu G, Alawneh S. Integrating wearables with cloud-based communication for health monitoring and emergency assistance. Internet Things 2018;1:40-54.
17. Wang SH, Ding Y, Zhao W, Huang YH, Perkins R, Zou W, *et al*. Text mining for identifying topics in the literatures about adolescent substance use and depression. BMC Public Health 2016;16:279.
18. Yang K, Meho LI. Citation analysis: A comparison of Google Scholar, Scopus, and Web of Science. Procee Am Soc Inf Sci Technol 2006;43:1-15.
19. Alcaraz C, Najera P, Lopez J, Roman R. Wireless sensor networks and the internet of things: Do we need a complete integration? In 1st International Workshop on the Security of the Internet of Things (SecIoT10); 2010.
20. Li S, Xu LD, Zhao S. The internet of things: A survey. Inf Syst Frontiers 2015;17:243-59.
21. Guest G, MacQueen KM, Namey EE. Applied Thematic Analysis. USA: Sage Publications; 2011.
22. Haley DF, Vo L, Parker KA, Frew PM, Golin CE, Amola O, *et al*. Qualitative methodological approach. In: O'Leary A, Frew PM, editors. Poverty in the United States: Women's Voices. Ch. 2. Cham: Springer International Publishing; 2017. p. 9-23.
23. MacQueen KM, Guest G. An introduction to team-based qualitative research. Handbook for Team-Based Qualitative Research. AltaMira Press, UK: 2008. p. 3-19.
24. MacQueen KM, McLellan E, Kay K, Milstein B. Codebook development for team-based qualitative analysis. CAM J 1998;10:31-6.
25. Namey E, Guest G, Thairu L, Johnson L. Data reduction techniques for large qualitative data sets. Handbook for Team-Based Qualitative Research. Vol. 2. AltaMira Press, UK: 2008. p. 137-61.
26. Saldaña J. The Coding Manual for Qualitative Researchers. London: Sage; 2015.
27. RQDA. What is RQDA and What are its Features? 2019. Available from: http://rqda.r-forge.r-project.org/. [Last accessed on 2019 Feb 18].
28. The R Project for Statistical Computing; 2019. Available from: https://www.r-project.org/. [Last accessed on 2019 Mar 31].
29. Haynes E, Garside R, Green J, Kelly MP, Thomas J, Guell C. Semi-automated text analytics for qualitative data synthesis. Res Synthesis Methods 2019;10:452-64. [doi: 10.1002/jrsm.1361].
30. Benoit K, Watanabe K, Wang H, Nulty P, Obeng A, Müller S, *et al*. Quanteda: An R package for the quantitative analysis of textual data. J Open Source Softw 2018;3:774.
31. Quick Start Guide Quanteda. Available from: https://quanteda.io/articles/quickstart.html. [Last accessed on 2019 Jun 03].
32. Patra J, Popova S, Rehm J, Bondy S, Flint R, Giesbrecht N. Economic Costs of Chronic Disease in Canada 1995-2003. Ontario chronic disease prevention alliance and the ontario public health association Canada; 2007. p. 1-37.
33. Malkovich L. Beginner's Guide to Text Analysis with Quanteda; 2018. Available from: https://data.library.virginia.edu/a-beginners-guide-to-text-analysis-with-quanteda/. [Last accessed on 2019 Jun 03].
34. Junny T. Text mining using Latent Dirichlet allocation (LDA) Algorithm; 2017. Available from: https://rpubs.com/Junny31/318845. [Last accessed on 2019 Mar 31].
35. MCC. Word Cloud Tutorial; 2018. Available from: https://rpubs.com/oaxacamatt/R-cran-TM. [Last accessed on 2019 Mar 31].
36. Mair P. Modern Psychometrics with R. Switzerland: Springer; 2018.
37. Sherman R. Business Intelligence Guidebook: From Data Integration to Analytics. Newnes; 2014.
38. Blei DM, Ng AY, Jordan MI. Latent dirichlet allocation. J Machine Learn Res 2003;3:993-1022.
39. Moro S, Cortez P, Rita P. Business intelligence in banking: A literature analysis from 2002 to 2013 using text mining and latent Dirichlet allocation. Expert Syst Appl 2015;42:1314-24.
40. Sugimoto CR, Li D, Russell TG, Finlay SC, Ding Y. The shifting sands of disciplinary development: Analyzing North American Library and Information Science dissertations using latent Dirichlet allocation. J Am Soc Inf Sci Technol 2011;62:185-204.
41. Wu Y, Liu M, Zheng WJ, Zhao Z, Xu H. Ranking gene-drug relationships in biomedical literature using latent Dirichlet allocation. In: Biocomputing 2012. Singapore: World Scientific; 2012. p. 422-33.
42. Dadkhah M, Lagzian M, Rahimnia F, Kimiafar K. What do websites say about internet of things challenges? A text mining approach. Sci Technol Lib 2020. (In Press).
43. Nikita M. Select Number of Topics for LDA Model; 2016. Available from: https://cran.r-project.org/web/packages/ldatuning/vignettes/topics.html. [Last accessed on 2019 Mar 31].
44. Silge J, Robinson D. Tidy Topic Modeling; 2018. Available from: https://cran.r-project.org/web/packages/tidytext/vignettes/topic_modeling.html. [Last accessed on 2019 Mar 31].
45. Saaty TL. A scaling method for priorities in hierarchical structures. J Math Psychol 1977;15:234-81.
46. Saaty TL. How to make a decision: The analytic hierarchy process. Eur J Oper Res 1990;48:9-26.
47. Saaty TL. Analytic hierarchy process. In: Gass S.I., Harris C.M. (eds) Encyclopedia of Operations Research and Management Science. New York, NY: Springer; 2001. p. 52-64.
48. Özdağoğlu A, Özdağoğlu G. Comparison of AHP and fuzzy AHP for the multi-criteria decision making processes with linguistic evaluations. İstanbul Ticaret Üniver Fen Bilimleri Derg 2007;6:65-85.
49. Wang YM, Chin KS. Fuzzy analytic hierarchy process: A logarithmic fuzzy preference programming methodology. Int J Approximate Reason 2011;52:541-53.
50. Chang DY. Applications of the extent analysis method on fuzzy AHP. Eur J Oper Res 1996;95:649-55.
51. Kubler S, Robert J, Derigent W, Voisin A, Le Traon Y. A state-of the-art survey & testbed of fuzzy AHP (FAHP) applications. Expert Syst Appl 2016;65:398-422.
52. Nabel EG, Stevens S, Smith R. Combating chronic disease in developing countries. Lancet 2009;373:2004-6.
53. Yach D, Kellogg M, Voute J. Chronic diseases: An increasing challenge in developing countries. Trans R Soc Trop Med Hyg 2005;99:321-4.
54. Kubler S, Derigent W, Voisin A, Robert J, Le Traon Y, Viedma EH. Measuring inconsistency and deriving priorities from fuzzy pairwise comparison matrices using the knowledge-based consistency index. Knowl Based Syst 2018;162:147-60.
55. Gogus O, Boucher TO. Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons. Fuzzy Sets Syst 1998;94:133-44.

56. Páez DG, Aparicio F, de Buenaga M, Ascanio JR. Big Data and IoT for Chronic Patients Monitoring. Cham, Switzerland: Springer; 2014. p. 416-23.
57. Jagadeeswari V, Subramaniyaswamy V, Logesh R, Vijayakumar V. A study on medical Internet of Things and Big Data in personalized healthcare system. Health Inf Sci Syst 2018;6:14.
58. Apte S, Petrovsky N. Will blockchain technology revolutionize excipient supply chain management? J Excipients Food Chem 2016;7:910.
59. Saravanan M, Shubha R, Marks AM, Iyer V. SMEAD: A Secured Mobile Enabled Assisting Device for Diabetics Monitoring. USA: IEEE; 2017. p. 1-6.
60. Gruber TR. Toward principles for the design of ontologies used for knowledge sharing? Int J Hum Comput Stud 1995;43:907-28.
61. La HJ, Jung HT, Kim SD. Extensible disease diagnosis cloud platform with medical sensors and IoT devices. In: 2015 3rd International Conference on Future Internet of Things and Cloud; 2015. p. 371-8.
62. Jara AJ, Zamora MA, Skarmeta AF. Drug identification and interaction checker based on IoT to minimize adverse drug reactions and improve drug compliance. Pers Ubiquitous Comput 2014;18:5-17.
63. Sangpetch O, Sangpetch A. Security context framework for distributed healthcare IoT platform. In: Ahmed MU, Begum S, Raad W, editors. Internet of Things Technologies for HealthCare. Springer, Cham: Springer International Publishing; 2016. p. 71-6.
64. Sun W, Cai Z, Li Y, Liu F, Fang S, Wang G. Security and privacy in the medical internet of things: A review. Security and Communication Networks; 2018.
65. Dwivedi AD, Srivastava G, Dhar S, Singh R. A decentralized privacy-preserving healthcare blockchain for IoT. Sensors (Basel) 2019;19:326.
66. Dadkhah M, Lagzian M, Santoro G. How can health professionals contribute to the Internet of Things body of knowledge? A phenomenography Study. VINE J Inf Knowl Manage Syst 2019;49: p. 299-40.
67. Arun R, Suresh V, Veni Madhavan CE, Narasimha Murthy MN. On finding the natural number of topics with latent dirichlet allocation: Some observations. In: Zaki MJ, Yu JX, Ravindran B, Pudi V, editors. Advances in Knowledge Discovery and Data Mining. Springer Berlin Heidelberg; 2010. p. 391-402.
68. Cao J, Xia T, Li J, Zhang Y, Tang S. A density-based method for adaptive LDA model selection. Neurocomputing 2009;72:1775-81.
69. Deveaud R, SanJuan E, Bellot P. Accurate and effective latent concept modeling for ad hoc information retrieval. Doc Numérique 2014;17:61-84.
70. Griffiths TL, Steyvers M. Finding scientific topics. Proc Natl Acad Sci U S A 2004;101 Suppl 1:5228-35.
71. Moor N. Ldatuning. Available from: https://github.com/nikita-moor/ldatuning. [Last accessed on 2019 Apr 01].
72. Casella G, George EI. Explaining the Gibbs sampler. Am Statistician 1992;46:167-74.
73. Bastani K, Namavari H, Shaffer J. Latent Dirichlet allocation (LDA) for Topic Modeling of the CFPB Consumer Complaints. arXiv preprint arXiv:180707468; 2018.
74. Chang J, Gerrish S, Wang C, Boyd-Graber JL, Blei DM. Reading tea leaves: How humans interpret topic models. In: Advances in Neural Information Processing Systems. Neural Information Processing Systems: Canada; 2009. p. 288-96.
75. Opazo Basaez M, Ghulam S, Arias Aranda D, Stantchev V. Smart healthcare services: A patient oriented cloud computing solution. In: The 3-Rd International Business Servitization Conference. At Bilbao, Spain; 2014.
76. Datta P, Namin AS, Chatterjee M. A Survey of Privacy Concerns in Wearable Devices. In: 2018 IEEE International Conference on Big Data (Big Data); 2018. p. 4549-53.
77. Granados J, Rahmani A, Nikander P, Liljeberg P, Tenhunen H. Towards energy-efficient HealthCare: An Internet-of-Things architecture using intelligent gateways. In: 2014 4th International Conference on Wireless Mobile Communication and Healthcare - Transforming Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH); 2014. p. 279-82.
78. Saaty TL, Özdemir MS. How many judges should there be in a group ? Ann Data Sci 2014;1:359-68.
79. Zubiaga A, Procter R, Maple C. A longitudinal analysis of the public perception of the opportunities and challenges of the Internet of Things. PLoS One 2018;13:e0209472.
80. Mohammadzadeh AK, Ghafoori S, Mohammadian A, Mohammadkazemi R, Mahbanooei B, Ghasemi R. A Fuzzy Analytic Network Process (FANP) approach for prioritizing internet of things challenges in Iran. Technol Soc 2018;53:124-34.
81. Kraemer FA, Braten AE, Tamkittikhun N, Palma D. Fog computing in healthcare – A review and discussion. IEEE Access 2017;5:9206-22.
82. Feinerer I, Hornik K. Tm: Text Mining Package. Package version 0.7-6; 2018. Available from: https://CRAN.R-project.org/package=tm. [Last accessed on 2020 May 03].
83. Feinerer I, Hornik K, Meyer D. Text mining infrastructure in R. J Stat Softw 2008;25:1-54.
84. Bouchet-Valat M. SnowballC: Snowball Stemmers Based on the C "libstemmer" UTF-8 Library; 2019. Available from: https://CRAN.R-project.org/package=SnowballC. [Last accessed on 2020 May 03].
85. Fellows I. Wordcloud: Word Clouds. Package version 2.6; 2018. Available from: https://CRAN.R-project.org/package=wordcloud. [Last accessed on 2020 May 03].
86. Neuwirth E. RColorBrewer: ColorBrewer Palettes. Package version 1.1-2; 2014. Available from: https://CRAN.R-project.org/package=RColorBrewer. [Last accessed on 2020 May 03].
87. Wickham H, Bryan J. Readxl: Read Excel Files; 2019. Available from: https://CRAN.R-project.org/package=readxl. [Last accessed on 2020 May 03].
88. Nikita M. Ldatuning: Tuning of the Latent Dirichlet allocation Models Parameters. Package version 0.2.2; 2017. Available from: https://github.com/nikita-moor/ldatuning. [Last accessed on 2020 May 03].
89. Grün B, Hornik K. Topicmodels: An R package for fitting topic models. J Stat Softw 2011;40:1-30.
90. Silge J, Robinson D. Tidytext: Text mining and analysis using tidy data principles in R. J Open Source Softw 2016;1:37. [doi: 10.21105/joss.00037].
91. Wickham H. Ggplot2: Elegant Graphics for Data Analysis. New York: Springer-Verlag; 2016. Available from: https://ggplot2.tidyverse.org. [Last accessed on 2020 May 03].
92. Wickham H, François R, Henry L, Müller K. Dplyr: A Grammar of Data Manipulation. Package version 0.8.0.1; 2019. Available from: https://CRAN.R-project.org/package=dplyr. [Last accessed on 2020 May 03].
93. Benoit K, Obeng A. Readtext: Import and Handling for Plain and Formatted Text Files. Package version 0.75; 2019. Available from: https://CRAN.R-project.org/package=readtext. [Last accessed on 2020 May 03].
94. Comtois D. Summarytools: Tools to Quickly and Neatly Summarize Data; 2019. Available from: https://CRAN.R-project.org/package=summarytools. [Last accessed on 2020 May 03].

BIOGRAPHIES

Mehdi Dadkhah obtained his PhD of Information technology management from Ferdowsi University of Mashhad, Iran. His current research interests are human computer interaction, social computing and research on emerging technologies.

Email: mehdidadkhah@mail.um.ac.ir

Mohammad Mehraeen is Professor of Information Systems at the Department of Management, Ferdowsi University of Mashhad, Iran. He obtained his Ph.D. from the University of Manchester, UK. His current research interests include; Electronic government, Digital transformation, Business Informatics, Big data and IoT.

Email: m-lagzian@um.ac.ir

Fariborz Rahimnia is a professor of management at Faculty of Economics and Administrative sciences, Ferdowsi University of Mashhad, Iran. He has several publications in various scholarly and professional journals, including Journal of Business Ethics, Information & Management, Computers in Human Behavior, Personnel Review, Benchmarking, Science and Technology Libraries.

Email: r-nia@um.ac.ir

Khalil Kimiafar is associate professor in health information management at the Mashhad University of Medical Sciences, Iran. His field of interest in health information technology and medical informatics include patient's registries, mobile health, evaluation of health information systems, social media, information needs, patient portals, telemedicine, electronic health record and internet of things.

Email: kimiafarkh@mums.ac.ir

Appendix 1

List of 186 selected papers based on Figure 1

1. Abdelaziz A, Salama AS, Riad A, Mahmoud AN. A Machine Learning Model for Predicting of Chronic Kidney Disease Based Internet of Things and Cloud Computing in Smart Cities Security in Smart Cities: Models, Applications, and Challenges. Cham: Springer; 2019. p. 93-114.
2. Abeledo MC, Bruschetti F, Aguilera G, Iriso P, Marsicano M, Lacapmesure A. Remote Monitoring of Elderly or Partially Disabled People Living in their Homes through the Measurement of Environmental Variables. Paper Presented at the IEEE CACIDI 2016-IEEE Conference on Computer Sciences; 2016.
3. Aghanavesi S, Westin J. A Review of Parkinson's Disease Cardinal and Dyskinetic Motor Symptoms Assessment Methods using Sensor Systems. Paper presented at the International Conference on IoT Technologies for HealthCare; 2016.
4. AL-Jaf TG, Al-Hemiary EH. Internet of Things Based Cloud Smart Monitoring for Asthma Patient. Paper Presented at the The 1st International Conference on Information Technology (ICoIT'17); 2017.
5. Al-Taee MA, Abood SN. Mobile acquisition and monitoring system for improved diabetes management using emergent wireless and web technologies. Int J Inf Technol Web Eng 2012;7:17-30.
6. Al-Taee MA, Al-Nuaimy W, Al-Ataby A, Muhsin ZJ, Abood SN. Mobile Health Platform for Diabetes Management Based on the Internet-of-Things. Paper Presented at the 2015 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT); 2015.
7. Al-Taee MA, Al-Nuaimy W, Muhsin ZJ, Al-Ataby A. Robot assistant in management of diabetes in children based on the Internet of things. IEEE Internet Things J 2017;4:437-45.
8. Al-Taee MA, Sungoor AH, Abood SN, Philip NY. Web-of-Things Inspired e-Health Platform for Integrated Diabetes Care Management. Paper Presented at the 2013 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT); 2013.
9. Alloghani M, Hussain A, Al-Jumeily D, Fergus P, Abuelma'Atti O, Hamden H. A mobile health monitoring application for obesity management and control using the internet-of-things. Paper Presented at the 2016 Sixth International Conference on Digital Information Processing and Communications (ICDIPC); 2016.
10. Altun AA, Başçıfcı N. A wireless sensor network based on zigbee for ECG monitoring system. Paper Presented at the 2011 5th International Conference on Application of Information and Communication Technologies (AICT); 2011.
11. Amira T, Dan I, Az-Eddine B, Ngo HH, Said G, Katarzyna WW. Monitoring Chronic Disease at Home Using Connected Devices. Paper presented at the 2018 13th Annual Conference on System of Systems Engineering (SoSE); 2018.
12. Anand IS, Greenberg BH, Fogoros RN, Libbus I, Katra RP; Music Investigators. Design of the Multi-Sensor Monitoring in Congestive Heart Failure (MUSIC) study: Prospective trial to assess the utility of continuous wireless physiologic monitoring in heart failure. J Card Fail 2011;17:11-6.

13. Angelidis PA. Personalised physical exercise regime for chronic patients through a wearable ICT platform. Int J Electron Healthc 2010;5:355-70.
14. Antonovici DA, Chiuchisan I, Geman O, Tomegea A. Acquisition and management of biomedical data using Internet of Things concepts. Paper Presented at the 2014 International Symposium on Fundamentals of Electrical Engineering (ISFEE); 2014.
15. Aquino-Santos R, Martinez-Castro D, Edwards-Block A, Murillo-Piedrahita AF. Wireless sensor networks for ambient assisted living. Sensors (Basel) 2013;13:16384-405.
16. Årsand E, Tatara N, Hartvigsen G. Wireless and Mobile Technologies Improving Diabetes Self-Management Handbook of Research on Mobility and Computing: Evolving Technologies and Ubiquitous Impacts. IGI Global; 2011. p. 136-56.
17. Atallah L, Lo B, Yang GZ, Siegemund F. Wirelessly Accessible Sensor Populations (WASP) for Elderly Care Monitoring. Paper Presented at the 2008 Second International Conference on Pervasive Computing Technologies for Healthcare; 2008.
18. Atreja A, Otobo E, Ramireddy K, Deorocki A. Remote Patient Monitoring in IBD: Current State and Future Directions. Curr Gastroenterol Rep 2018;20:6.
19. Azariadi D, Tsoutsouras V, Xydis S, Soudris D. ECG signal analysis and arrhythmia detection on IoT wearable medical devices. Paper presented at the 2016 5th International conference on modern circuits and systems technologies (MOCAST); 2016.
20. Baig MM, Gholamhosseini H, Connolly MJ. A comprehensive survey of wearable and wireless ECG monitoring systems for older adults. Med Biol Eng Comput 2013;51:485-95.
21. Basanta H, Huang YP, Lee TT. Intuitive IoT-based H2U healthcare system for elderly people. Paper presented at the 2016 IEEE 13th International Conference on Networking, Sensing, and Control (ICNSC); 2016.
22. Bayo-Monton JL, Martinez-Millana A, Han W, Fernandez-Llatas C, Sun Y, Traver V. Wearable sensors integrated with internet of things for advancing ehealth care. Sensors 2018;18:1851.
23. Bhattasali T, Chaki N. Heterogeneous services in layered framework of iot enabled assisted living. Paper presented at the Proceedings of the First Workshop on IoT-enabled Healthcare and Wellness Technologies and Systems; 2016.
24. Boyer EW, Smelson D, Fletcher R, Ziedonis D, Picard RW. Wireless technologies, ubiquitous computing and mobile health: Application to drug abuse treatment and compliance with HIV therapies. J Med Toxicol 2010;6:212-6.
25. Brill J. The internet of things: Building trust and maximizing benefits through consumer control. Fordham L Rev 2014;83:205.
26. Bryant N, Spencer N, King A, Crooks P, Deakin J, Young S. IoT and smart city services to support independence and wellbeing of older people. Paper Presented at the 2017 25th International Conference on Software, Telecommunications and Computer Networks (SoftCOM); 2017.
27. Bui N, Zorzi M. Health care applications: A solution based on the internet of things. Paper Presented at the Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies; 2011.
28. Buzzi MC, Buzzi M, Trujillo A. Healthy aging through pervasive predictive analytics for prevention and rehabilitation of chronic conditions. Paper presented at the Proceedings of the 3rd 2015 Workshop on ICTs for Improving Patients Rehabilitation Research Techniques; 2015.
29. Caldara M, Comotti D, Galizzi M, Locatelli P, Re V, Alimonti D, *et al*. A novel body sensor network for Parkinson's disease patients rehabilitation assessment. Paper Presented at the 2014 11th International Conference on Wearable and Implantable Body Sensor Networks; 2014.
30. Cancela J, Pastorino M, Tzallas A, Tsipouras M, Rigas G, Arredondo M, Fotiadis D. Wearability assessment of a wearable system for Parkinson's disease remote monitoring based on a body area network of sensors. Sensors 2014;14:17235-55.
31. Chatterjee P, Cymberknop LJ, Armentano RL. IoT-based decision support system for intelligent healthcare–applied to cardiovascular diseases. Paper Presented at the 2017 7th International Conference on Communication Systems and Network Technologies (CSNT); 2017.
32. Chatterjee S, Byun J, Dutta K, Pedersen RU, Pottathil A, Xie H. Designing an Internet-of-Things (IoT) and sensor-based in-home monitoring system for assisting diabetes patients: Iterative learning from two case studies. Eur J Inf Syst 2018;27:670-85.
33. Chen M, Ma Y, Song J, Lai CF, Hu B. Smart clothing: Connecting human with clouds and big data for sustainable health monitoring. Mobile Netw Appl 2016;21:825-45.
34. Chiarini G, Ray P, Akter S, Masella C, Ganz A. mHealth technologies for chronic diseases and elders: A systematic review. IEEE J Selected Areas Commun 2013;31:6-18.
35. Chiauzzi E, Rodarte C, DasMahapatra P. Patient-centered activity monitoring in the self-management of chronic health conditions. BMC Med 2015;13:77.
36. Chiuchisan I, Geman O. An approach of a decision support and home monitoring system for patients with neurological disorders using internet of things concepts. WSEAS Trans Syst 2014;13:460-9.
37. Cho KR, Yoon TB. Implementation of NFC-Based Smart-Drug Information Management System Advances in Computer Science and Ubiquitous Computing. Singapore: Springer; 2017. p. 795-804.
38. Chong ZH, Tee YX, Toh LJ, Phang SJ, Liew JY, Queck B, Gottipati S. Predicting Potential Alzheimer Medical Condition in Elderly Using IOT Sensors-Case Study; 2017.
39. Chouvarda IG, Goulis DG, Lambrinoudaki I, Maglaveras N. Connected health and integrated care: Toward new models for chronic disease management. Maturitas 2015;82:22-7.
40. Chung AE, Jensen RE, Basch EM. Leveraging emerging technologies and the "Internet of Things" to improve the quality of cancer care. J Oncol Pract 2016;12:863.
41. Chung PC. Impacts of IoT and Wearable Devices on Healthcare. Paper presented at the Proceedings of the 12th International Conference on Advances in Mobile Computing and Multimedia; 2014.
42. Couturier J, Sola D, Borioli G, Raiciu C. How can the internet of things help to overcome current healthcare challenges. Commun Strateg 2012;87:67-81.

43. Darshan K, Anandakumar K. A comprehensive review on usage of Internet of Things (IoT) in healthcare system. Paper Presented at the 2015 International Conference on Emerging Research in Electronics, Computer Science and Technology (ICERECT); 2015.
44. Datta SK, Bonnet C, Gyrard A, Da Costa RP, Boudaoud K. Applying Internet of Things for personalized healthcare in smart homes. Paper Presented at the 2015 24th Wireless and Optical Communication Conference (WOCC); 2015.
45. Dieffenderfer J, Goodell H, Mills S, McKnight M, Yao S, Lin F, *et al*. Low-power wearable systems for continuous monitoring of environment and health for chronic respiratory disease. IEEE J Biomed Health Inform 2016;20:1251-64.
46. Dieffenderfer JP, Goodell H, Bent B, Beppler E, Jayakumar R, Yokus M, *et al*. Wearable wireless sensors for chronic respiratory disease monitoring. Paper presented at the 2015 IEEE 12th International Conference on Wearable and Implantable Body Sensor Networks (BSN); 2015.
47. Dilmaghani RS, Bobarshad H, Ghavami M, Choobkar S, Wolfe C. Wireless sensor networks for monitoring physiological signals of multiple patients. IEEE Trans Biomed Circuits Syst 2011;5:347-56.
48. Dlodlo N. Potential applications of the internet of things technologies for South Africa's Health Services. Adv Inf Technol Appl Comput (ISSN 2251-3418) 2013;1:180-8.
49. Dlodlo N, Foko TE, Mvelase P, Mathaba S. The state of affairs in internet of things research. TheElectronic Journal Information Systems Evaluation 2012;15:244-58.
50. Dobkin BH. A rehabilitation-internet-of-things in the home to augment motor skills and exercise training. Neurorehabil Neural Repair 2017;31:217-27.
51. Dohr A, Modre-Opsrian R, Drobics M, Hayn D, Schreier G. The Internet of Things for Ambient Assisted Living. Paper Presented at the 2010 Seventh International Conference On Information Technology: New Generations; 2010.
52. Dorsey ER, Vlaanderen FP, Engelen LJ, Kieburtz K, Zhu W, Biglan KM, *et al*. Moving Parkinson care to the home. Movement Disord 2016;31:1258-62.
53. Fan X, Xie Q, Li X, Huang H, Wang J, Chen S, *et al*. Activity recognition as a service for smart home: Ambient assisted living application via sensing home. Paper Presented at the 2017 IEEE International Conference on AI & Mobile Services (AIMS); 2017.
54. Fanucci L, Saponara S, Bacchillone T, Donati M, Barba P, Sánchez-Tato I, Carmona C. Sensing devices and sensor signal processing for remote monitoring of vital signs in CHF patients. IEEE Trans Instrum Meas 2013;62:553-69.
55. Fonseca MA. Development of Implantable Wireless Pressure Sensors for Chronic Disease Management; 2008.
56. García L, Tomás J, Parra L, Lloret J. An m-health application for cerebral stroke detection and monitoring using cloud services. Int J Inf Manage 2019;45:319-27.
57. Gatouillat A, Badr Y, Massot B, Sejdić E. Internet of medical things: A review of recent contributions dealing with cyber-physical systems in medicine. IEEE Internet Things J 2018;5:3810-22.
58. Ghose A, Guo X, Li B. Empowering Patients using Smart Mobile Health Platforms: Evidence from a Randomized Field Experiment; 2017.
59. Gill S, Hearn J, Powell G, Scheme E. Design of a multi-sensor IoT-enabled assistive device for discrete and deployable gait monitoring. Paper presented at the 2017 IEEE Healthcare Innovations and Point of Care Technologies (HI-POCT); 2017.
60. Godfrey A. Wearables for independent living in older adults: Gait and falls. Maturitas 2017;100:16-26.
61. Gomes BD, Muniz LC, e Silva S, Ríos FJ, Ríos LE, Endler M. A comprehensive and scalable middleware for ambient assisted living based on cloud computing and internet of things. Concurr Comput 2017;29:e4043.
62. Gómez J, Oviedo B, Zhuma E. Patient monitoring system based on internet of things. Procedia Comput Sci 2016;83:90-7.
63. Gope P, Hwang T. BSN-Care: A secure IoT-based modern healthcare system using body sensor network. IEEE Sensors J 2016;16:1368-76.
64. Granulo E, Bećar L, Gurbeta L, Badnjević A. Telemetry system for diagnosis of Asthma and Chronical Obstructive Pulmonary Disease (COPD). Paper presented at the International Conference on IoT Technologies for HealthCare; 2016.
65. Haahr RG, Duun S, Thomsen EV, Hoppe K, Branebjerg J. A wearable "electronic patch" for wireless continuous monitoring of chronically diseased patients. Paper presented at the 2008 5th International Summer School and Symposium on Medical Devices and Biosensors; 2008.
66. Haghi M, Thurow K, Stoll R. Wearable devices in medical internet of things: Scientific research and commercially available devices. Healthc Inform Res 2017;23:4-15.
67. Hariharan R. Wearable Internet of Things Examining Developments and Applications of Wearable Devices in Modern Society. IGI Global; 2018. p. 29-57.
68. Hiremath S, Yang G, Mankodiya K. Wearable Internet of Things: Concept, architectural components and promises for person-centered healthcare. Paper presented at the 2014 4th International Conference on Wireless Mobile Communication and Healthcare-Transforming Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH); 2014.
69. Huang Y, Zhai X, Guo F, Ali S, Liu R. Chronic diseases based on cloud computing platform (hypertension) intelligent control system design and analysis. Int J Comput Eng Res 2016;6:1-4.
70. Hussain A, Wenbi R, Xiaosong Z, Hongyang W, da Silva AL. Personal home healthcare system for the cardiac patient of smart city using fuzzy logic. J Adv Inf Technol 2016;7:58-64.
71. Hussain SA, Singh AV, Ramaiah CS, Hussain SJ. A wireless device for patient ECG monitoring and motion activity recording for medical applications. Paper presented at the 2016 5th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO); 2016.
72. Istepanian RS. The potential of Internet of Things (IoT) for assisted living applications. Paper presented at the IET Seminar on Assisted Living 2011; 2011.
73. Istepanian RS, Hu S, Philip NY, Sungoor A. The potential of Internet of m-health Things "m-IoT" for non-invasive glucose level sensing. Paper presented at the 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2011.
74. Jagadeeswari V, Subramaniyaswamy V, Logesh R, Vijayakumar V. A study on medical Internet of Things and Big Data in personalized

healthcare system. Health Inf Sci Syst 2018;6:14.
75. Jagtap PT, Bhosale NP. IOT Based Epilepsy Monitoring using Accelerometer sensor. Paper presented at the 2018 International Conference on Information, Communication, Engineering and Technology (ICICET); 2018.
76. Jara AJ, Zamora-Izquierdo MA, Skarmeta AF. Interconnection framework for mHealth and remote monitoring based on the internet of things. IEEE J Selected Areas Commun 2013;31:47-65.
77. Jara AJ, Zamora MA, Skarmeta AF. An internet of things–based personal device for diabetes therapy management in ambient assisted living (AAL). Personal Ubiquitous Comput 2011;15:431-40.
78. Jara AJ, Zamora MA, Skarmeta AF. Drug identification and interaction checker based on IoT to minimize adverse drug reactions and improve drug compliance. Personal Ubiquitous Comput 2014;18:5-17.
79. Jeong DU, Kew HP. Real-time monitoring of ubiquitous wearable ECG sensor node for healthcare application. Paper Presented at the International Conference on Computational Science and Its Applications; 2009.
80. Jeong S, Kim YW, Youn CH. Personalized healthcare system for chronic disease care in cloud environment. ETRI J 2014;36:730-40.
81. Jiménez-Fernández S, de Toledo P, del Pozo F. Usability and interoperability in wireless sensor networks for patient telemonitoring in chronic disease management. IEEE Trans Biomed Eng 2013;60:3331-9.
82. Johnson P, Andrews DC, Wells S, de Lusignan S, Robinson J, Vandenburg M. The use of a new continuous wireless cardiorespiratory telemonitoring system by elderly patients at home. J Telemed Telecare 2001;7 Suppl 1:76-7.
83. Juen J, Cheng Q, Prieto-Centurion V, Krishnan JA, Schatz B. Health monitors for chronic disease by gait analysis with mobile phones. Telemed J E Health 2014;20:1035-41.
84. Kakria P, Tripathi N, Kitipawang P. A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors. Int J Telemed Appl 2015;2015:8.
85. Kang G. Wireless eHealth (WeHealth)–From concept to practice. Paper presented at the 2012 IEEE 14th International Conference on e-Health Networking, Applications and Services (Healthcom); 2012.
86. Kazi S, Bajantri G, Thite T. Remote heart rate monitoring system using IoT. IRJET 2018;5:2956-3.
87. Khallouki H, Bahaj M, Roose P. Smart Emergency Alert System Using Internet of Things and Linked Open Data for Chronic Disease Patients. Paper presented at the International Conference on Advanced Intelligent Systems for Sustainable Development; 2018.
88. Kim SH, Chung K. Emergency situation monitoring service using context motion tracking of chronic disease patients. Cluster Comput 2015;18:747-59.
89. Kirtana R, Lokeswari Y. An IoT based remote HRV monitoring system for hypertensive patients. Paper presented at the 2017 International Conference on Computer, Communication and Signal Processing (ICCCSP); 2017.
90. Klímová B, Kuča K. Internet of things in the assessment, diagnostics and treatment of Parkinson's disease. Health Technol 2019;9:87-91.
91. Koshmak G. An Android Based Monitoring and Alarm System Forpatients with Chronic Obtrusive Disease; 2011.
92. Kouris I, Koutsouris D. Application of data mining techniques to efficiently monitor chronic diseases using wireless body area networks and smartphones. Universal J Biomed Eng 2013;1:23-31.
93. Kouris I, Koutsouris D. Identifying risky environments for COPD patients using smartphones and internet of things objects. Int J Computational Intell Stud 2014;3:1-17.
94. Kumar PM, Gandhi UD. A novel three-tier Internet of Things architecture with machine learning algorithm for early detection of heart diseases. Comput Electr Eng 2018;65:222-35.
95. Kumar S, Rai S, Shanaz Z, Raja S. Chronic health patientmonitoring system using IOT. Int J Recent Innov Trends Comput Commun 2018;6:114-9.
96. Kvedar JC, Fogel AL, Elenko E, Zohar D. Digital medicine's march on chronic disease. Nature Biotechnol 2016;34:239.
97. La HJ, Ter Jung H, Kim SD. Extensible disease diagnosis cloud platform with medical sensors and IoT devices. Paper presented at the 2015 3rd International Conference on Future Internet of Things and Cloud; 2015.
98. Lake D, Milito RM, Morrow M, Vargheese R. Internet of things: Architectural framework for ehealth security. J ICT Standardization 2014;1:301-28.
99. Laksanasopin T, Suwansri P, Juntaramaha P, Keminganithi K, Achalakul T. Point-of-Care Device and Internet of Things Platform for Chronic Disease Management. Paper presented at the 2018 2nd International Conference on Biomedical Engineering (IBIOMED); 2018.
100. Laplante PA, Kassab M, Laplante NL, Voas JM. Building caring healthcare systems in the internet of things. IEEE Syst J 2018;12:3030-7.
101. LeMoyne R, Mastroianni T, Cozza M, Coroian C, Grundfest W. Implementation of an iPhone for characterizing Parkinson's disease tremor through a wireless accelerometer application. Paper Presented at the 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology; 2010.
102. Li B, Dong Q, Downen RS, Tran N, Jackson JH, Pillai D, *et al*. A wearable IoT aldehyde sensor for pediatric asthma research and management. Sensors Actuators B Chem 2019;287:584-94.
103. Li C, Hu X, Zhang L. The IoT-based heart disease monitoring system for pervasive healthcare service. Procedia Comput Sci 2017;112:2328-34.
104. Li D, Park HW, Batbaatar E, Munkhdalai L, Musa I, Li M, Ryu KH. Application of a mobile chronic disease health-care system for hypertension based on big data platforms. J Sensors 2018;2018:1-13.
105. Li X, Kang G, Zhang Y, Zhang X, Chen L, Lee L. Chronic disease management system with body-implanted medical devices based on Wireless Sensor Networks. Paper presented at the 2012 IEEE 14th International Conference on e-Health Networking, Applications and Services (Healthcom); 2012.
106. Liu Y, Niu J, Yang L, Shu LeBPlatform: An IoT-based system for NCD patients homecare in China. Paper presented at the 2014 IEEE Global Communications Conference; 2014.

107. Lo G, Suresh AR, Stocco L, González-Valenzuela S, Leung VC. A wireless sensor system for motion analysis of Parkinson's disease patients. Paper presented at the 2011 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops); 2011.
108. López-de-Ipiña D, Díaz-de-Sarralde I, Zubía JG. An ambient assisted living platform integrating RFID data-on-tag care annotations and Twitter. J UCS 2010;16:1521-38.
109. Lotfi A, Langensiepen C, Moreno PA, Gómez EJ, Chernbumroong S. An ambient assisted living technology platform for informal carers of the elderly-icarer. EAI Endorsed Trans Pervas Health Technol 2017;3:152393.
110. Ma Y, Wang Y, Yang J, Miao Y, Li W. Big health application system based on health internet of things and big data. IEEE Access 2017;5:7885-97.
111. Mahmoud MM, Rodrigues JJ, Ahmed SH, Shah SC, Al-Muhtadi JF, Korotaev VV, *et al*. Enabling technologies on cloud of things for smart healthcare. IEEE Access 2018;6:31950-67.
112. Mainetti L, Patrono L, Secco A, Sergi I. An IoT-aware AAL system for elderly people. Paper presented at the 2016 International Multidisciplinary Conference on Computer and Energy Science (SpliTech); 2016.
113. Mainetti L, Patrono L, Secco A, Sergi I. An IoT-aware AAL System to Capture Behavioral Changes of Elderly People; 2017.
114. Maksimović M, Vujović V, Perišić B. Do It Yourself solution of Internet of Things Healthcare System: Measuring body parameters and environmental parameters affecting health. J Inf Syst Eng Manage 2016;1:25-39.
115. Mamaghanian H, Khaled N, Atienza D, Vandergheynst P. Compressed sensing for real-time energy-efficient ECG compression on wireless body sensor nodes. IEEE Trans Biomed Eng 2011;58:2456-66.
116. Manisha M, Neeraja K, Sindhura V, Ramaya P. Iot on heart attack detection and heart rate monitoring. Int J Innov Eng Technol 2016;7:459-66.
117. McHale SA, Pereira E, Weishmann U, Hall M, Fang H. An IoT Approach to Personalised Remote Monitoring and Management of Epilepsy. Paper presented at the 2017 14th International Symposium on Pervasive Systems, Algorithms and Networks & 2017 11th International Conference on Frontier of Computer Science and Technology & 2017 Third International Symposium of Creative Computing (ISPAN-FCST-ISCC); 2017.
118. Montefiore A, Parry D, Philpott A. A Radio Frequency Identification (RFID)-based wireless sensor device for drug compliance measurement. Health Informatics New Zealand, Wellington; 2010.
119. Muriuki IM. Fuzzy Expert Based Real Time Monitoring System for Patients with Chronic Heart Failure through IOT. Strathmore University; 2018.
120. Naseer A, Alkazemi BY, Waraich EU. A big data approach for proactive healthcare monitoring of chronic patients. Paper presented at the 2016 Eighth International Conference on Ubiquitous and Future Networks (ICUFN); 2016.
121. Niazmand K, Tonn K, Kalaras A, Fietzek UM, Mehrkens JH, Lueth TC. Quantitative evaluation of Parkinson's disease using sensor based smart glove. Paper presented at the 2011 24th International Symposium on Computer-Based Medical Systems (CBMS); 2011.
122. Nunes L, Estrella J, Nakamura L, de Libardi R, Ferreira C, Jorge L, *et al*. A distributed sensor data search platform for internet of things environments. arXiv preprint arXiv: 1606.07932; 2016.
123. Op den Akker H, Tabak M, Perianu MM, Jones VM, Hofs D, Tönis T, *et al*. Development and evaluation of a sensor-based system for remote monitoring and treatment of chronic diseases-the continuous care & coaching platform. Paper presented at the Proceedings of the 6th International Symposium on eHealth Services and Technologies, EHST 2012; 2012.
124. Otto C, Milenkovic A, Sanders C, Jovanov E. System architecture of a wireless body area sensor network for ubiquitous health monitoring. J Mobile Multimedia 2006;1:307-26.
125. Páez DG, Aparicio F, de Buenaga M, Ascanio JR. Big data and IoT for chronic patients monitoring. Paper presented at the International Conference on Ubiquitous Computing and Ambient Intelligence; 2014.
126. Pallikonda Rajasekaran M, Radhakrishnan S, Subbaraj P. Ambulatory monitoring of free living patients affected by Chronic Obstructive Pulmonary Disease (COPD) and Parkinson's Disease (PD) using Wireless Sensor Networks. Int J Biomed Eng Technol 2010;4:111-22.
127. Panagiotou C, Antonopoulos C, Keramidas G, Voros N, Hübner M. IoT in Ambient Assistant Living Environments: A View from Europe Components and Services for IoT Platforms. Switzerland: Springer; 2017. p. 281-98.
128. Parthasarathy P, Vivekanandan S. A typical IoT architecture-based regular monitoring of arthritis disease using time wrapping algorithm. Int J Comput Appl 2018;42:1-11.
129. Pasluosta C, Gassner H, Winkler J, Klucken J, Eskofier B. Parkinson's disease as a working model for global healthcare restructuration: The internet of things and wearables technologies. Paper presented at the Proceedings of the 5th EAI International Conference on Wireless Mobile Communication and Healthcare; 2015.
130. Pasluosta CF, Gassner H, Winkler J, Klucken J, Eskofier BM. An emerging era in the management of Parkinson's disease: Wearable technologies and the internet of things. IEEE J Biomed Health Inf 2015;19:1873-81.
131. Patil P, Waichal R, Kumbhar U, Gadkari V. Patient health monitoring system using IOT. Int Res J Eng Technol 2017;4:638-41.
132. Pawar S, Deshmukh H. A Survery on e-Health Care Monitoring for Heart Care Using IOT. Paper presented at the 2018 International Conference on Inventive Research in Computing Applications (ICIRCA); 2018.
133. Pennell NA, Dicker AP, Tran C, Jim HSL, Schwartz DL, Stepanski EJ. mHealth: Mobile technologies to virtually bring the patient into an oncology practice. Am Soc Clin Oncol Educ Book 2017;37:144-54.
134. Petrenko A, Roenko N. Personal Healthcare Platform for Chronic Diseases with Mobile Self-Management Support. EDIS - Publishing Institution of the University of Zilina; 2016:4;248-53.
135. Piao XZ, Piao HY, Yang S, Xue YS. An IoT-Based early Warning System for Patients with Heart Disease. Paper presented at the Applied Mechanics and Materials; 2013.

136. Qi J, Yang P, Min G, Amft O, Dong F, Xu L. Advanced internet of things for personalised healthcare systems: A survey. Pervasive Mobile Comput 2017;41:132-49.
137. Raad M, Sheltami T. RFID Based Telemedicine System for Localizing Elderly with Chronic Diseases. Paper Presented at the International Conference on IoT Technologies for HealthCare; 2016.
138. Raad MW, Sheltami T, Shakshuki E. Ubiquitous tele-health system for elderly patients with Alzheimer's. Procedia Comput Sci 2015;52:685-9.
139. Raina A, Abraham WT, Adamson PB, Bauman J, Benza RL. Limitations of right heart catheterization in the diagnosis and risk stratification of patients with pulmonary hypertension related to left heart disease: Insights from a wireless pulmonary artery pressure monitoring system. J Heart Lung Transplant 2015;34:438-47.
140. Raji A, Jeyasheeli PG, Jenitha T. IoT based classification of vital signs data for chronic disease monitoring. Paper presented at the 2016 10th International Conference on Intelligent Systems and Control (ISCO); 2016.
141. Ray PP. Home Health Hub Internet of Things (H 3 IoT): An architectural framework for monitoring health of elderly people. Paper presented at the 2014 International Conference on Science Engineering and Management Research (ICSEMR); 2014.
142. Rodríguez-Rodríguez I, Zamora MÁ, Rodríguez JV. Towards a New Diabetes Mellitus Management by Means of Novel Biosensors and Information and Communication Technologies. Paper presented at the Proceedings of the 2017 4th International Conference on Biomedical and Bioinformatics Engineering; 2017.
143. Rohokale VM, Prasad NR, Prasad R. A cooperative Internet of Things (IoT) for rural healthcare monitoring and control. Paper presented at the 2011 2nd International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE); 2011.
144. Romero LE, Chatterjee P, Armentano RL. An IoT approach for integration of computational intelligence and wearable sensors for Parkinson's disease diagnosis and monitoring. Health Technol 2016;6:167-72.
145. Rotariu C, Manta V. Wireless system for remote monitoring of oxygen saturation and heart rate. Paper Presented at the 2012 Federated Conference on Computer Science and Information Systems (FedCSIS); 2012.
146. Rotariu C, Manta V, Ciobotariu R. Remote cardiac arrhythmia monitoring system using wireless sensor networks. Paper presented at the 11th International Conference on Development and Application Systems, Suceava, Romania; May, 2012.
147. Ruiz-Fernández D, Marcos-Jorquera D, Gilart-Iglesias V, Vives-Boix V, Ramírez-Navarro J. Empowerment of patients with hypertension through BPM, IoT and Remote sensing. Sensors (Basel) 2017;17:2273.
148. Salunke P, Nerkar R. IoT driven healthcare system for remote monitoring of patients. J Modern Trend Sci Technol 2017;3:100-3.
149. Santos A, Macedo J, Costa A, Nicolau MJ. Internet of things and smart objects for M-health monitoring and control. Procedia Technol 2014;16:1351-60.
150. Saravanan M, Shubha R, Marks AM, Iyer V. SMEAD: A secured mobile enabled assisting device for diabetics monitoring. Paper presented at the 2017 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS); 2017.
151. Senthilkumar R, Ponmagal R, Sujatha K. Efficient health care monitoring and emergency management system using IoT. Int J Control Theory Appl 2016;9:137-45.
152. Seto EY, Giani A, Shia V, Wang C, Yan P, Yang AY, *et al*. A wireless body sensor network for the prevention and management of asthma. Paper presented at the 2009 IEEE International Symposium on Industrial Embedded Systems; 2009.
153. Sinnapolu G, Alawneh S. Integrating wearables with cloud-based communication for health monitoring and emergency assistance. Internet Things 2018;1:40-54.
154. Siow E, Tiropanis T, Hall W. Analytics for the internet of things: A survey. ACM Comput Surv 2018;51:1-36.
155. Sogamoso KV, Parra OJ. Internet of Things for Epilepsy Detection in Patients. Paper Presented at the International Conference on Cooperative Design, Visualization and Engineering; 2018.
156. Spyropoulos B. Towards internet of things supported active ageing and home-care. Biomedical Statistics and Informatics 2017;2:77-86.
157. Storni C. Design challenges for ubiquitous and personal computing in chronic disease care and patient empowerment: A case study rethinking diabetes self-monitoring. Personal Ubiquitous Comput 2014;18:1277-90.
158. Swan M. Sensor mania! the internet of things, wearable computing, objective metrics, and the quantified self 2.0. J Sensor Actuator Netw 2012;1:217-53.
159. Synnott J, Chen L, Nugent CD, Moore G. WiiPD—An approach for the objective home assessment of Parkinson's disease. Paper presented at the 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2011.
160. Taccini N, Loriga G, Pacelli M, Paradiso R. Wearable monitoring system for chronic cardio-respiratory diseases. Paper presented at the 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2008.
161. Talboom JS, Huentelman MJ. Big data collision: The internet of things, wearable devices and genomics in the study of neurological traits and disease. Hum Mol Genet 2018;27:R35-9.
162. Talpur MS, Liu W, Wang G. A ZigBee-based elderly health monitoring system: Design and implementation. Int J Auton Adapt Commun Syst 2014;7:393-411.
163. Tarassenko L, Clifton D. Semiconductor wireless technology for chronic disease management. Electron Lett 2011;47:30-2.
164. Thaduangta B, Choomjit P, Mongkolveswith S, Supasitthimethee U, Funilkul S, Triyason T. Smart healthcare: Basic health check-up and monitoring system for elderly. Paper Presented at the 2016 International Computer Science and Engineering Conference (ICSEC); 2016.
165. Toh SH, Lee SC, Chung WY. WSN based personal mobile physiological monitoring and management system for chronic disease. Paper Presented at the 2008 Third International Conference on Convergence and Hybrid Information Technology; 2008.
166. Toumpaniaris P, Iliopoulou D, Lazakidou A, Katevas N, Koutsouris D. A survey for chronic diseases management and the related sensors in the ambient assisted living environment. Int J Health Res Innov 2014;2:65-84.

167. Tsipouras MG, Tzallas AT, Karvounis EC, Tsalikakis DG, Cancela J, Pastorino M, *et al*. A wearable system for long-term ubiquitous monitoring of common motor symptoms in patients with Parkinson's disease. Paper Presented at the IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI); 2014.
168. Usher W, Laakso EL, James D, Rowlands D. The connective matrix of emerging health technologies: E-Health solutions for people with chronic disease. Int J E Health Med Commun 2013;4:94-114.
169. Varatharajan R, Manogaran G, Priyan M, Sundarasekar R. Wearable sensor devices for early detection of Alzheimer disease using dynamic time warping algorithm. Cluster Comput 2018;21:681-90.
170. Velasco CA, Mohamad Y, Ackermann P. Architecture of a web of things ehealth framework for the support of users with chronic diseases. Paper presented at the Proceedings of the 7th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-Exclusion; 2016.
171. Vergara PM, de la Cal E, Villar JR, González VM, Sedano J. An IoT platform for epilepsy monitoring and supervising. J Sensors 2017;2017:1-17.
172. Verma AS, Mhetre MR. ECG Monitoring System Based on Internet of Things Technology. Paper presented at the International Conference on Intelligent Data Communication Technologies and Internet of Things; 2018.
173. Wang A, An N, Xia Y, Li L, Chen GA Logistic Regression and Artificial Neural Network-Based Approach for Chronic Disease Prediction: A Case Study of Hypertension. Paper presented at the 2014 IEEE International Conference on Internet of Things (iThings), and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom); 2014.
174. Wang C, Wang Q, Shi S. A distributed wireless body area network for medical supervision. Paper presented at the 2012 IEEE International Instrumentation and Measurement Technology Conference Proceedings; 2012.
175. Wang J, Cheng Z, Zhang M, Zhou Y, Jing L. Design of a situation-aware system for abnormal activity detection of elderly people. Paper presented at the International Conference on Active Media Technology; 2012.
176. Xu B, Xu L, Cai H, Jiang L, Luo Y, Gu Y. The design of an m-Health monitoring system based on a cloud computing platform. Enterprise Inf Syst 2017;11:17-36.
177. Yahyaie M, Tarokh MJ, Mahmoodyar MA. Use of internet of things to provide a new model for remote heart attack prediction. Telemed J E Health 2019;25:499-510.
178. Yang H, Chai J. A portable wireless ECG monitor based on MSP430FG439. Paper presented at the 2011 International Conference on Intelligent Computation and Bio-Medical Instrumentation; 2011.
179. Yoo H, Chung K. PHR based diabetes index service model using life behavior analysis. Wireless Personal Commun 2017;93:161-74.
180. Yuehong Y, Zeng Y, Chen X, Fan Y. The internet of things in healthcare: An overview. J Indian Inf 2016;1:3-13.
181. Zhang H, Liu K, Kong W, Tian F, Yang Y, Feng C, *et al*. A mobile health solution for chronic disease management at retail pharmacy. Paper Presented at the 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom); 2016.
182. Zhang Q, Su Y, Yu P. Assisting an elderly with early dementia using wireless sensors data in smarter safer home. Paper Presented at the International Conference on Informatics and Semiotics in Organisations; 2014.
183. Zhongyan L. Analysis of Smart Glucose Meter Stability from the Economic Perspective. Boletín Técnico; 2017. p. 58.
184. Zhou X, Lu Y, Chen M, Bao SD, Miao F. A method of ECG template extraction for biometrics applications. Paper presented at the 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2014.
185. Zhu N, Diethe T, Camplani M, Tao L, Burrows A, Twomey N, *et al*. Bridging e-health and the internet of things: The sphere project. IEEE Intell Syst 2015;30:39-46.
186. Zschippig C, Kluss T. Gardening in ambient assisted living. Urban For Urban Green 2016;15:186-9.