Review Study of Digital Health-related Solutions to Control COVID-19 Pandemic: Analysis for the 10 Highest Prevalent Countries

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Abstract

Background: The new coronavirus COVID-19 as a case of pneumonia becomes a global pandemic, affecting most of the countries around the world. digital health as information technologies that can be applied in three aspects including digital patients, digital devices, and digital clinics could help against this pandemic.

Objective: Recent reviews examine the role of digital health in controlling COVID-19 with the objective of identifying the potential of digital health to fight disease however this study is aimed to review and analyze applied information technology and strategies to control the COVID-19 pandemic in ten countries with the highest prevalence of the disease in April the first 2020.

Methods: For this review, Google Scholar, PubMed, Web of Science and Scopus databases were searched in April 2020 to retrieve publications from December 2019 to 31 March 2020. Furthermore, Google search engine was also investigated to identify additional applications of digital health for COVID-19 pandemic control.

Results: Ten papers were included in this review. Most of the studies were conducted in China. The digital tools were mostly aimed at distributing widespread information and tracking real-time transmissions. Most of the papers were considered the whole population in their researches. prevention has been the most popular objective for controlling the disease in the papers followed by screening.

Conclusions: Having considered the potential of available information technologies across the world in the 21st century, particularly in developed countries, it seems that more digital health products have remained to be applied for viral infection and other health crisis management.

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The authors report no conflict of interest.

Abstract

Background

The novel coronavirus disease (COVID-19) as a case of pneumonia becomes a global pandemic, affecting most of the countries around the world. digital health as information technologies that can be applied in three aspects including digital patients, digital devices, and digital clinics could help against this pandemic.

Objective

Recent reviews have examined the role of digital health in controlling COVID-19 to identify the potential of digital health to fight against the disease. However, this study is aimed at reviewing and analyzing applied digital technology to control the COVID-19 pandemic in ten countries with the highest prevalence of the disease.

Methods

For this review, Google Scholar, PubMed, Web of Science, and Scopus databases were searched in August 2020 to retrieve publications from December 2019 to 15 March 2020. Furthermore, the Google search engine was also investigated to identify additional applications of digital health for COVID-19 pandemic control.

Results

32 papers were included in this review reported 37 digital health applications for COVID-19 control. Most of the projects for COVID-19 fighting were telemedicine visit (N=11, 30%). Digital learning packages for informing about the disease (N=7, 19%), GIS and QR code application for real-time case tracking (N=7, 19%), as well as cloud /mobile based systems for self-care and patient tracking (N=7, 19%) were in the second rank of digital tool applications. projects deployed by collaboration of European countries, USA, Australia, and China.

Conclusion

Having considered the potential of available information technologies across the world in the 21st century, particularly in developed countries, it seems that more digital health products with higher level of intelligence capability have remained to be applied for pandemic and health related crisis management.

Keywords: COVID-19, Digital Health, Information Technology, Telemedicine, Electronic Health

Introduction

The novel coronavirus disease (COVID-19) was originally recognized in December 2019 as a case of pneumonia in Wuhan, China, and has since become a global pandemic, affecting most of the countries around the world[1]. On March 11, the World Health Organization announced the outbreak of a pandemic and asked for coordinated mechanisms to support readiness and rapid response to the infection across the world's health sectors[2]. While the incidence of COVID-19 continues to rise, healthcare systems are rapidly facing growing clinical demands[3]. Operational management of a pandemic in the era of modern medicine is requiring novel technologies and their capabilities such as digital health to support the management of COVID-19 cases in different stages[4]. The digital health with the meaning of application of information technology has been already used to improve health care organizations such as ‘NHS Digital’ in the UK[5]. Also, digital health is defined as information technologies that can be applied in three aspects including digital patients, digital devices, and digital clinics. The digital patient indicates that whether patients use and engage with mHealth devices to change and sustain their behavior and it consists of technologies of telemedicine & patient self-measurements, and digital retention. Digital device aspects clear how they help to solve clinical problems essentially and are composed of smartphone-connected rhythm monitoring devices, wireless and wearable devices, and implantable and ingestible sensors. The digital clinic aspect focuses on how they can generate mHealth data, analyze it so that it is clinically meaningful, and integrate it within clinical workflows. Digital clinics consists on precision-based mHealth and N-of-1 designs, population-based mHealth in resource-limited areas, and mHealth regulation and integration[6].

During the pandemic of COVID-19, digital health-based tools may support organizations and societies more efficiently. They aid in the instant widespread information distribution, real-time transmission tracking, virtual venues creation for meetings and official day-to-day operations, and offering telemedicine visits for patients[7-12]. These applications for COVID-19 have been reported in several publications [13-15]. During the recent months of the outbreak of COVID-19 that

countries and their responsible organizations such as health ministries and other officials have focused to control the pandemic, many supportive and reliable informatics infrastructure has been developed[12]. They were applied in practice to prepare for managing an exponential increase in COVID-19-infected patients. The various digital health strategies have been used for disease control in different countries. A study carried out e by Calton et al.[16], suggested some tips regarding applying telemedicine as a means to reduce the transmission of COVID-19. The focus of the study conducted by Moazzami et al. [17] is on employing telemedicine to prevent disease among healthcare providers. In study conducted by Keesara et al. [18]refers to the capabilities and potential of digital health to fight the disease.; however, they have reviewed the digital health related solutions in general view to address how this technology can support the health care systems through introducing various strategic roles such as surveillance, screening, triage, diagnosis, and monitoring, and contact tracing; and no data regarding using these appcoching in practice for fighting against COVID-19 have been provided[19]. Fagherazzi et al. emphasized on the huge potential of digital technology for COVID-19 control to be considered on the top level of the health system and the challenges that the policy makers may face during the crisis control using digital solutions[20]. Furthermore, in a macro vision the required re-structured society and environment for digital health technology application have been revealed including healthcare system, government, public, industry, environment, and energy in order to use digital technology for COVID-19 control successfully [15]. These reviews are depecting a general image regarding the requirement of digital system usages and thier applications around the global [21] with no focus on any specific application in a specific country or region. Although these works have shed light on the topic of digital health soloutions applied for COVID-19 control, there is a gap of deep understanding regading these technologies applications in high prevelant countries.

Therefore, this study is aimed to review and analyze applied information technology and digital health-related strategies to control the COVID-19 pandemic in ten countries with the highest

prevalence of the disease.

Methods

In this review study the databases of Google Scholar, PubMed, Web of Science, and Scopus were searchedin August 2020 to retrieve publications from December 2019 to 15 August 2020.. The combination of keywords for searching was as follows:

("Corona virus" OR "COVID 19" OR "coronavirus") AND (computer OR internet OR web* OR mobile OR smart OR email OR videoconfer* OR telecommunication OR ICT OR "information technology" OR ehealth OR telehealth OR mHealth OR telecare OR telehealth OR telemedicine OR telemonitoring OR digital OR wearable OR IoT OR cloud) AND (Italy OR Spain OR USA OR France OR UK OR Iran OR China OR Netherlands OR Germany OR Belgium)

Inclusion criteria were publications that introduce digital health applications to manage and control COVID-19 in humans, and exclusion criteria were non-English publications, publications with no abstract, researchers for data analysis and prediction of epidemiological parameters modeling, letter to editor and review studies. Data were analyzed using descriptive methods.. The qualitative analysis of the included studies was done based on predefined categories. A summary of the reviewed articles was summarized in Table 1. Several items were analyzed in each paper including 1) publication month, 2)Country (Italy, Spain, USA, France, UK, Iran, China, Netherlands, Germany, and Belgium) as they were the most prevalent countries according to the worldometers website , 3)purpose of study including screening, prevention, diagnosis, treatment, and follow up the cases; each were defined as follow: screening: no symptom+ no contact with COVID-19 patients, prevention: no symptom + contact with COVID-19 patients with no symthom, diagnosis:having disease symptoms, treatment of COVID-19 cases: decreasing the symthoms dramatically, and follow-up: discharged cases with the least symthoms, 4)Scope and Territory (village, City, Region/province, State, Country, and international), 5) Digital tools including (Robots, IoT,

Videoconferencing, Web-based systems, Cloud-based systems, Wearable devices, CDSS, Intelligent systems, Smartphones, Mobile apps, Telecommunication systems, websites and digital media, and Digital QR code.

Table1. the details of reviewed papers to apply digital tools for COVID-19 control purposes.

Author	Journal	Publication-Month	Country	Purpose	Scope and Territory	Applied Digital Tools (might be more than one)	Type of digital application
Kamel, B. and Geraghty, EM [22]	Int J Health Geogr	Mar-20	China	Prevention	Internationally	Web-based systems, Mobile Apps, GIS	To distribute widespread information, 2) to track real-time transmission
Yang et al. [23]	Clin Oral Investig	Mar-20	China	Treatment and Follow-up	Country	Web-based systems, Mobile Apps	To offer telemedicine visits for patients
Meng et al. [24]	Int J Clin Pharm	Apr-20	China	Treatment	Region	Cloud-based systems, Smartphones, Telecommunication systems	The pharmaceutical care activities provided to patients and physicians by pharmacists
Ohannessian et al. [25]	JMIR Public Health Surveill	Feb-20	France	Prevention	Country	Videoconferencing	To offer telemedicine visits for patients
Pan, X et al. 21[26]	Microbes and Infection	Feb-20	China	Prevention	Country	Mobile apps	To distribute widespread information, to track real-time transmission
Pan XB [27]	Irish Journal of Medical Science	Mar-20	China	Screening and Prevention	City and Country	Mobile apps	To track real-time transmission
Sun, Q et al.[28]	Annals of Intensive Care	Mar-20	China	Treatment	State	Intelligent systems	Early warning system and screening procedures for patients
Hernandez-Garcia and Gimenez-Julvez [29]	JMIR Public Health Surveill	Apr-20	A collaboration of the USA, Spain, Switzerland, UK, Sweden, and Canada	Screening and Prevention	International	Websites and digital media	To distribute widespread information

Hua and Shaw [30]	Int J Environ Res Public Health	Mar-20	China	Screening, Prevention, and Follow-up	Region/ province	Web-based systems, Smartphones, websites, and digital media, digital QR code	To distribute widespread information, to track real-time transmission, “Rumors exposed website to inform about fake news and rumors,
Drew, et al [31]	Science	May-20	UK, USA	Screening	International	Mobile app	To distribute widespread information, to track real-time transmission
Franco, et al [32]	Global Spine Journal	June-20	USA	Treatment	State	Video conferencing, Telephone	To offer telemedicine visits for patients
Gilbert, et al [33]	BMJ Open Quality	May-20	UK	Prevention	City	Video conferencing, Telephone	To offer telemedicine visits for patients
Giudice, et al [34]	International Journal of Environment Research and Public Health	May-20	Italy	Follow up	Region	Video conferencing	To offer telemedicine visits for patients
Gong, et al [35]	Journal of Medical Internet Research	April-20	China	Prevention	Country	Telecommunication system	To offer telemedicine visits for patients
Gong, et al [36]	Journal of Medical Internet Research	April-20	China	Screening	City	Cloud-Based System, Mobile app, CDSS	To screen cases and detect patients
Goodman, et al [37]	Journal of Medical Internet Research	April-20	Spain	Prevention	Country	Telecommunication system (TeleVision-based ASSistive)	To distribute widespread information, to support home care and patients selfcare
Grange, et al[38]	Applied Clinical Informatics	April-20	USA	Prevention, Diagnosis, Treatment, Screenin	State	Video conferencing, CDSS, Telecommunication system	To offer telemedicine visits for patients

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Grenda, et al [39]	Annals of Surgery	August-20	USA	Diagnosis, Treatment	City	Telecommunication system, Video conferencing,	To offer telemedicine visits for patients
Grossman, et al [40]	Neurology	June-20	USA	diagnosis, Treatment	City	Smart phone, mobile apps	To offer telemedicine visits for patients
Hames, et al [41]	Journal of Psychotherapy Integration	April-20	USA, Canada	Prevention	Country	Telecommunication system	Training
Hanna, et al[42]	Modern Pathology	June-20	USA	Prevention, Diagnosis	City	Telecommunication system	Diagnosis
Hom, et al [43]	Journal of Psychotherapy Integration	April-20	USA	Prevention, Treatment	City	Video conferencing	To offer telemedicine visits for patients, Training
Itamura, et al [44]	OTO Open	April-20	USA	Prevention	Country	Video conferencing	To offer telemedicine visits for patients
Judson, et al [45]	Journal of the American Medical Informatics Association	June-20	USA	Prevention	State	Website	To screen cases and detect patients
Wu, et al [46]	European Respiratory Journal	June-20	China, Italy, Belgium	Diagnosis	International	CDSS	To classify patients in triage in order to find the best route
Wang, et al [47]	Jmir Mhealth and Uhealth	June-20	China	Prevention	Country	Mobile app (WeChat)	Early tracing and quarantine of potential sources of infection
Timmers et al[48]	MIR Mhealth Uhealth	June-20	Netherland	Prevention	Country	Mobile app	Education, Self-Assessment, and Symptom Monitoring
Pepin, et al[49]	Journal of Medical Internet Research	June-20	France	Prevention	International	Wearable devices and Activity trackers	The define the level of quarantine
Rabuna, et al[50]	Telemedicine and E-Health	June	Spain	Prevention	Rural Area	TELEA digital web platform	Real time patients tracking and monitoring, and

							follow up through calling patient by phone, videoconference, e-mail
Cheng, et al[51]	Community Mental Health Journal	July-20	USA, Canada, Australia	Prevention	International	Mobile app	Peer-to-peer psychological support for the Wuhan healthcare professionals at the front line of crisis
Castaldi, et al[52]	Acta Biomed	July-20	Italy	Prevention	Region	Social Media	To assess the dynamic burden of social anxiety through analysis the data of Facebook and Twitter
Blake, et al[53]	International Journal of Environmental Research and Public Health	July-20	UK	Prevention	Country	Digital learning package using Agile methodology	To provide psychologically safe spaces for staff through providing three steps e-package evidence-based guidance

Results

Searching scientific databases and manual searches retrieved 771 relevant articles. The title and abstract of all retrieved publications were evaluated by two of the authors. Disagreements between two evaluators were discussed and resolved by consensus. After duplication removal, 292 articles remained as in this stage. Then, 260 publications were removed because they couldn't meet the inclusion criteria. Afterward, the full text of the remained publications (n=32) was reviewed by four of the authors independently. The reviewed papers were studied according to the given variables as shown in table 1 and the following sections based on the different distribution.

According to the purpose of the study, the published studies until August 15 2020 were reviewed. The survey showed that 32 papers were conducted to show the application of digital health to fight the pandemic of coronavirus. The distribution by publication month revealed that the publication of

studies in terms of digital health and coronavirus began in February 2020 and the distribution of publication based on the month of publication is as follows: February:2, March: 5, April: 9, May:3, June: 9, July:3, and August (by half):1 paper.

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The projects of digital health application for COVID-19 control deployed in different geography, from international level to rural scale. Six international projects carried out by 6 countries at the most with collaboration of European countries, USA, China and even Australia. The digital health projects in international level mainly aimed to track real time transmission and infected cases, define the level of quarantine, and peer-to-peer consultation for supporting care providers in the other countries phytologically and scientifically. The most frequent digital health project for the given purpose conducted in country level (N=10), and the other geographical level were done in state(N=4), region (N=3), city(N=8), and rural(N=1). USA has been the country with the highest number(N=12) and in the different geographical scales (including international (N=3), state(N=3), country(N=2), city(N=4)) of digital health projects for covid-19 fighting. Afterwards, other studied countries ranked in terms of number of conducted projects including China(N=11), UK(N=4), Canada, Spain, and Italy(N=3), Belgium and France(N=2), and Netherland(N=1) projects respectively.

To show the applied approaches of digital health for the certain method of COVID 19 control the results were analyzed and all papers were categorized into six domains. These categories, their frequency& percentage, and their usages for COVID-19 control are presented in Table 2. Some articles have mentioned more than one approach to using digital health in controlling coronavirus.

Table 2- The frequency of digital health methods and their applications for COVID-19 pandemic control .

#	The applied digital health solutions	COVID-19 control approaches	Number and percentage of projects of digital health application
1	Digital learning package, mobile	To distribute widespread information	7, 19%

	apps and web-based systems		
2	GIS, QR-Code, and wearable devices	To track real-time transmission, activity tracking, and quarantine level analysis	7, 19%
3	Web based systems and mobile apps, videoconferencing and telephone	Telemedicine visit service and virtual venues for meetings	11, 30%
4	Cloud and mobile based system	Self-care and patient monitoring, training and diagnosis	7, 19%
5	Intelligent systems and CDSS	Early warning and detection, screening and triage	4, 10%
6	Social Media	Dynamic burden of pandemic and its consequences analysis	1, %3

According to the results, telemedicine visit service (N=11, 30%), has been the most applied approach in the pandemic control. Then, using electronic method to inform about the disease, the way to prevent the disease spread and protection ways were the second ranked approaches(19%), beside the other two solutions; they were using GIS, QR-Code, and wearable devices for real time transmission tracking as well as cloud based and mobile apps usage for patient monitoring and selfcare at home (19%). There were a few works regarding the application of intelligent systems, clinical decision support systems (10%), and social media data analysis (3%) for screening and burden of disease analysis purposes respectively.

Discussion

The COVID-19 pandemic has moved across the globe, costing lives and bringing upheaval and change to societies and economies. While the world's scientific community is racing towards effective vaccines or therapeutics, the most essential defense remains the most essential of public health measures, such as personal hygiene and mass physical distancing. To meet these two main aims, digital health and information technologies have come to support health systems and offered an opportunity to reshape current health care systems. This study aimed to review the most significant digital health tools applied to fight against COVID 19 in 10 countries which are in the list of the most affected ones. These tools aid the governments and people to take strategies controlling coronavirus pandemic through addressing the most urgent needs including the immediate outbreak response and impact mitigation. China as the first country affected by the virus[54] and the most populous country in the world with many researchers that worked and are working on multiple

aspects of the coronavirus is the most frequent origin country of the included studies. The burden of the virus could be massive in populous countries; thus, these studies are worth for investment in these countries. Those studies which reported the model development to predict epidemiological indicators were ignored as they have yielded no digital tool yet and need to be developed more [55-58].

Distributing widespread information and tracking real-time transmission were the two most frequent goals of the studies. The former might be originated from the importance of prevention in pandemic diseases as well as the simplest task of utilizing information systems, and the latter might be in the literature focus since the obtained knowledge from the previous experience of epidemics such as influenza and Zika[59-61]. Besides, Telemedicine visits for patients might be beneficial for populations in terms of screening and follow-up patients to deliver social distancing for the population[62]. It seems that investigating the infrastructures needed for this technology could have great potential in these types of crises. Besides the whole population that could be benefited from digital health technologies, there should be more attention on these tools' interventions on passengers as there might spread the virus to other locations and even globally[63].

As there are shown that cell phones could be beneficial for healthcare[64] and the high influence of them among global populations these tools are well suited to be used for distributing widespread information among populations. Mobile apps also were used for tracking real-time transmissions of the virus. Other potential useful tools that digital health provides are web-based apps and websites; these tools could also be used for distributing information and tracking transmission. Video conferencing and telecommunication is also seeming to be useful as a barrier to the spread of the disease by establishing social distance. Also, other industries might use teleservices to prevent the dissemination of the disease.

Due to time limitations and different time for onset of epidemy in different countries, several digital health tools are dismissed in this paper. There are reported in the news and other resources and it might be valuable to discuss them as learned lessons for other countries fighting with COVID-19. Here, we have reviewed digital health interventions in different countries according to their available facilities and other requirements.

China

In China, Multiple approaches are used for managing the pandemic ranging from web-based and mobile based systems to cloud based, CDSS, and intelligent systems. The total cases of COVID-19 in this country showed a slight increase after 01-March-2020 based on [65] data. Although, the decrease in COVID-19 cases affects from multiple factors and the eHealth tools attributed effect on

the decrease should be evaluated. China has applied an eHealth app named health code in a wide range to indicate a person's health status from the past day [66].

China planned to spend approximately US$1.4 trillion on digital infrastructure. This infrastructure upgrade program includes development of 5G networks, industrial internet, data centers, AI [67] than could help the country capability to fight against pandemics.

Italy and Spain

Despite of Spain, Italy ranked in the four less advanced European countries Based on Digital Economy and Society Index published by European Commission and about half of the population in Spain have not enough digital literacy[68]. The adoption of technology for prevention and managing the pandemic is not remarkable in these two countries. Although they have been developed coronavirus-tracking app[69]. The statistics of total COVID-19 cases shows a dramatic increase after 01-March-2020 in both countries[65]. It seems that the counties should invest more on technologies to manage pandemic.

USA

The US government launches a portal [70] for public that contains information for preventing and managing the coronavirus. Also, the Center for Disease Control and Prevention website [71] contains more detailed medical information on the spread mechanism of the virus, symptoms, prevention and treatment[72].

France and Belgium

The French app StopCovid has been developed to trace infected people with the aim of controlling the spread of the virus. Privacy concern arises for adopting the app. The Belgium has announced that a similar app adoption has been cancelled because of these issues [73].

UK

The National Health Service (NHS) of the UK is working on 9 main areas to digitally response to the pandemic the areas include providing digital channels for citizen guidance and trigae, enable remote and collaborative care with systems and data, deliver digital services for NHS Test and Trace, Identify and protect vulnerable citizens, Support planning with data, analysis and dashboards, Get data and insights to research communities, Support clinical trials, Provide secure infrastructure and support additional capacity, Plan for recovery, restarting services and new needs. the government categorize initiatives on these areas [74].

Iran

Although there were no included papers for this country, Iranian Ministry of Health developed a national screening program website [75] for identifying COVID-19 cases in the early stages.

Netherlands

The country is one of the leading countries in Europe in digital healthcare and data. About 90% of the population have digital records The Dutch government invests over 400 million euros for digital health. The Netherlands hospitals sign up in COVID-19 online portal for sharing patient information. video consultation is provided by more than 8,000 healthcare provider**s [76].**

Germany

The Health Innovation Hub, established by Germany's Ministry of Health, published a list of trusted telemedicine applications. The apps services include remote consultation, risk assessment and telemedicine services. Before 2018, the country didn't allow remote consultations. After passing the Digital Care Act by the German parliament it was allowed that is crucial for fighting against the pandemic [77].

Telemedicine systems are highly utilized in countries. In European countries tracking patients were adopted due to feasibility in small scale countries, also home care and self-care are relatively focused in these countries. Intelligent systems, CDSS and Intelligent triage systems are not well adopted maybe because of their need of supplying with data. The data is gathering around the globe. Furthermore, analysis of social health data could be interesting although little research is done in this regard. Figure 1 shows the extent of technologies developed for fighting against COVID-19 pandemic in the literature.

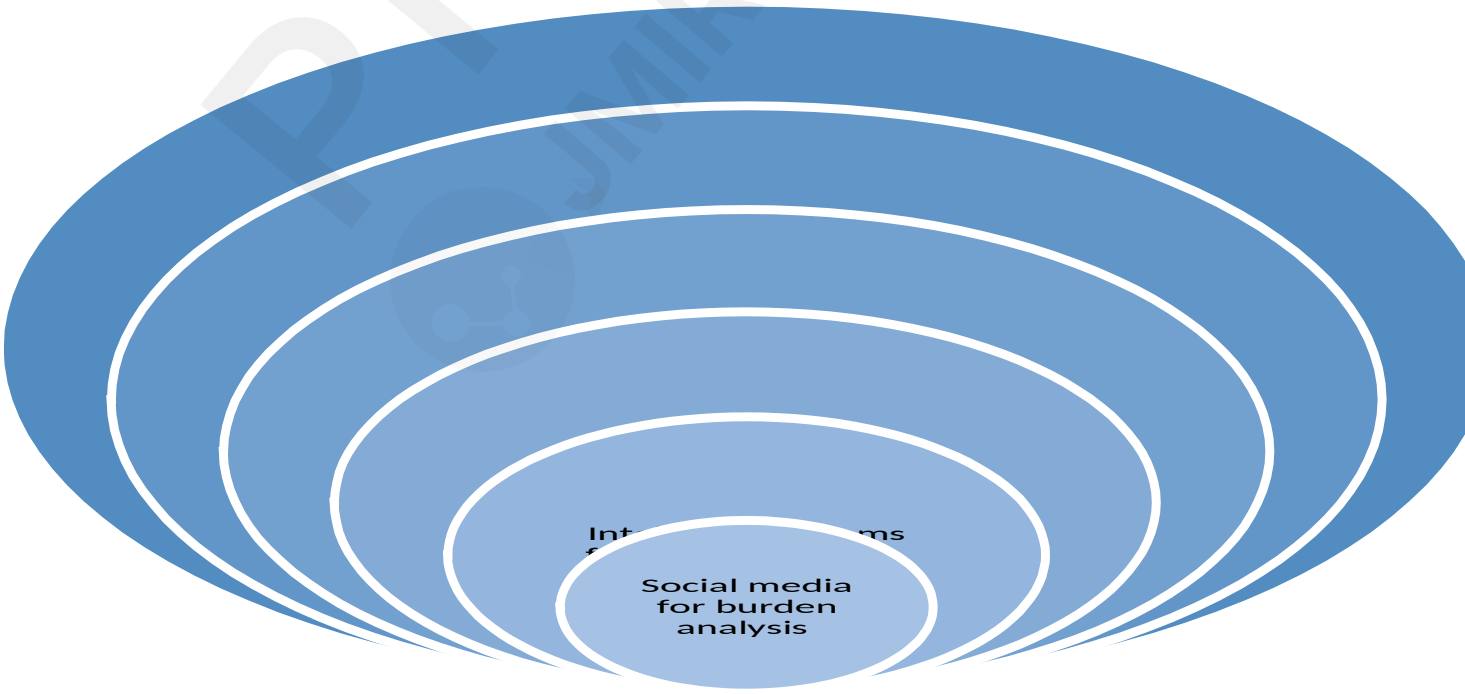

Figure 1. The current technologies for fighting against COVID-19

All in all, in studied countries after stating the alarm regarding the pandemic, eHealth strategies implementation started immediately. Mobile health solution and large-scale deployment of virtual consultation launched. Data analysis approaches applied to support decision-makers and also, websites and electronic training tools used to improve patient's protection behaviors. Although this study presents the applied digital tools for pandemic control in general, it has a lack of exact outcome evaluation after utilizing the digital health tools; thus, further studies are needed to evaluate the effects and outcomes of utilizing digital health tools. This could help health policymakers to make decisions regarding the investment of these tools and control the disease.

Conclusion

This study reviewed the reported digital health tools to fight against COVD-19 in ten countries in which they are in the list of high prevalence countries. Although there is not an equal strategy for applying digital health tools across the affected countries for the pandemic control, they have been the most primary policies that governmental and private companies thought about for disease control. China where the country that affected earlier and applied a greater number of digital tools such as epidemiological indicators analysis platforms, drones, robots, mobile apps, training websites, and educational media, videoconferencing, smart infection detectors, intelligent patients' tracers, and telemedicine systems. Also, the US have used developed many technologies to fight against the pandemic. Having considered the potential of available information technologies across the world in the 21st century, particularly in developed countries, it seems that more digital health products especially intelligence products have remained to be created and applied for viral infection and other health crisis management.

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