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Public Health Innovations Through Network Systems and Internet Technologies: A Review

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ABSTRACT

The Internet of Network Systems (IoNS) is a groundbreaking integration of networked devices, digital platforms, and powerful data analytics that is transforming the provision, monitoring and administration of health care. This research target is to assess IoNS effects on the health industry, focusing on its application in disease surveillance, telemedicine, remote patient monitoring, and data-driven decision-making. In the same context, we discuss the theoretical frameworks, methods, benefits of IoNS, and the problems and limitations concerning its adoption. Such problems and limitations involve data privacy, interoperability, and the digital divide. Last but not least, we highlight directions for further investigations and actions, especially regarding the introduction of modern technologies such as 5G, blockchain, and artificial intelligence IoT devices that can improve IoNS capabilities in the health sector. The review aims to explain in detail how IoNS is transforming the health sector and for better patient outcomes by collating existing literature.

Keywords: Community Health, Public health interventions, Social networks, Social support.

1. INTRODUCTION

The IoNS incorporates interconnected devices, digital platforms, and sophisticated data analytics into transformative healthcare systems. The ultimate shift in healthcare is fostering the integration of IoT – The Internet of Network Systems. This core works alongside wearable technology, smart medical devices, and real-time sensors that gather and relay health data for transmission and collection over the internet. These systems are embedded within broader network infrastructures, including social networks, cloud computing platforms, and telecommunication systems, to create a seamless ecosystem for healthcare delivery.

Through the implementation of the Internet of Things (IoT), it has become feasible to differentiate between "health data" in the process of analysing and diagnosing a physician following the use of physical sensor systems [1-3]. The reduction of the burden of maintenance is the most significant advantage of the Internet of Things (IoT) in healthcare, followed by an increase in the likelihood of receiving treatment [4]. The inclusion of the individual and online healthcare network was a wonderful learning experience, and it was predicted that the proliferation of mobile information and general technology-killing applications would bring about the growth of cloud health services. The Internet of Things (IoT) is already being provided as a main platform for monitoring neurological awareness [5]. Due to the lack of effective, accessible monitoring equipment, it is feasible to take several risks that are significantly higher.

IoT and other technologies are utilised in this context. This kind of caution is intended to serve the patient's best interests. Many sensors are utilised to analyse patient information. When it comes to health care, the carer is able to provide proper instruction. On the other hand, this benefits the quality of care. In the end, this results in expenditures associated with care. The Internet of Things (IoT) plays a significant role in the healthcare industry, as seen in the picture below.

The Internet of Things can find particular applicability in the area of public health [6-8] (figure 1). This is because public health is a field where communication with large numbers of individuals is implicitly required, either for data capture or public health intervention. In addition, many of the data inputs required for public health information capture are increasingly available via the proliferation of consumer health and fitness sensors.

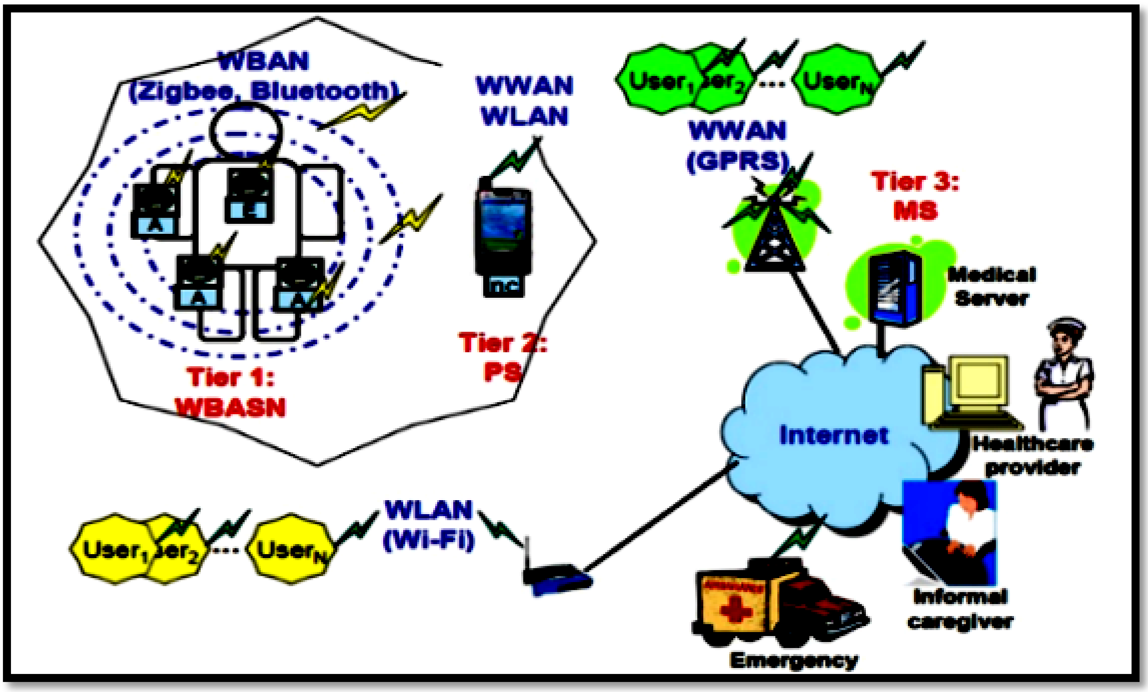

Figure 1: System architecture for rural area network for healthcare IoT [8].

A new generation of public health information systems. While increasingly, mobile devices and sensors are used as tools for individual health data capture, tracking and feedback, the use of such technologies has not to date extended into use for public health purposes. In addition, the use of sensors for individual fitness and health tracking does not as critically require an IoT infrastructure as does public health, as individual fitness tracking does not necessarily require widespread interconnectivity between many sensors and processors –such individual fitness and health data only strictly needs to be made available to the individual user [9-10].

There are a lot of applications and areas that apply the principles and models of the industry. The models can typically be adapted to any system that has Internet of Things (IoT) capabilities. The Internet of Things (IoT) calls for the use of a cloud environment to communicate, store data and connect different devices [11]. The devices could be connected to different places through networks using the developed capabilities of wireless communication.

IoNS fosters patient engagement and empowerment by providing individuals with access to their health data and personalised insights, enabling them to take a more active role in managing their health. Once again, mHealth apps can leverage data from IoT peripherals to recommend appropriate changes to diet, exercise, and even lifestyle. Even if the above statement sounds optimistic, there are already existing challenges connected with the use of IoNS in healthcare. Data protection is a common concern because these processes significantly augment the collecting and sharing of sensitive healthcare information, which malicious parties can target. Patient privacy should always be maintained [12]. Therefore, laws such as the Health Insurance Portability and Accountability Act (HIPAA) or General Data Protection Regulation (GDPR) are extremely important to abide by.

The digital divide is one of the most pronounced challenges, taking into consideration the fact that higher age and lack of resources create further gaps in the already existing health gaps [14]. Another challenge is the fact that the devices and systems are so much more disparate that there is a growing need for structured protocols to allow proper communication between platforms. Lastly, physicians hoping to leverage IoNS will also, painful as it might sound,

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require constant retraining to keep up with the sharp rate of change in technology. Other ethical concerns, such as AI algorithm bias and automation impact on the workforce, should also be evaluated to ensure that all demographics are catered to and taken into account when handled.

The subsequent development of IoNS in the healthcare setup appears to be bright, with advanced technologies like 5G, edge computing, and blockchain technology being favourable toward this enhancement.

2. LITERATURE REVIEW

Many recent studies have put forth the advancement of public health innovation through the utilisation of network systems and internet technologies, such as improving the surveillance of diseases, health promotion, and the delivery of healthcare services. As found in the work of [14], monitoring of chronic diseases is now possible in real-time, thanks to IoT-integrated devices. A study [15] that social media greatly assisted in disseminating health information during the COVID-19 pandemic.

Other studies [16] and [17] have examined the use of telemedicine in rural and other neglected areas and reported improved patient outcomes. Balasubramanian, Sreejith, et al. [18], as well as Choi, Min Hyuk, et al. [19], have shown the use of AI-powered analytics for predictive purposes to enhance disease resource allocation and identify outbreaks. Zobair, Khondker Mohammad, et al. [20], together with Atkinson, Jessica, et al. [21], initiated an interdisciplinary program that focused on telemonitoring and responsive interventions with the aim of addressing health problems like obesity and its related complications. Argyris, Young Anna, et al. [22] also mentioned the effective use of mobile health behavioural change interventions like physical activity and healthy eating, where Mhealth apps significantly improved the behaviour of patients.

Cenat, Jude Mary, et al.[23] explained the role that online platforms and online support groups have in maintaining mental health and ending smoking behaviour. In the public health domain, Zukaib, Umer, et al. [24] and Saeed, Gul, et al. [25] worked on the application of blockchain technology to protect data and ensure a more integrated health system functioning. Nishi, Stephanie K. et al. [26] and Goh, Khang Wen, et al. [27] used gamified vaccination campaigns and social challenges. They managed to engage more populations for vaccination. On the other hand, Molina-Guzmán et al. [28] and Kagai, Francis, et al. [29] discussed the issue of 5G networks that will assist in sending data without delay during emergency and disaster response situations. Other works, including Al Rajhi, Youssef Abdulaziz Abdulrahman, et al. [30]; Siddique, Muhammad, et al. [31]; Pilati, Francesco, et al [32]; Singh, David E., et al [33] focused on several issues, including the tracking and forecasting of the spread of infectious diseases with the use of big data analytics, as well as the modelling of public health interventions with digital twins.

White et al. [34] and Seneviratne et al. [35] have shown that the use of chat boxes and intelligent virtual assistants helps in the mental health and health education processes. Finally, more recently, Tran et al. [36] and Lopes, Henrique et al. [37] advanced geospatial technologies for mapping health inequalities and targeting appropriate actions. As indicated in the studies done by Capecchi, Irene et al. [38], and Abbas, Jonathan R., et al. [39], augmented reality and virtual reality are becoming increasingly common in health training and education. These studies exemplify the emerging use of internet and network system technologies in public health and the exercise of its correlating challenges, such as data privacy, misinformation, and digital equity, and providing room for innovation in the field.

3. IONS IN HEALTHCARE

The Internet of Networked Systems (IoNS) has been on the rise in recent years, transforming the healthcare industry with its emerging use. The area of IoNS application in healthcare is extremely vast. Some of the notable areas of impact include:

1. Maintaining a real-time watch on patients: The integration of the IoT into the health sector is a major step in monitoring the quality of patient care, operational efficiency, and health outcomes. Integration of IoT (Internet of Things) into the health industry. The aim of IoT integration into healthcare is to revolutionise patient care. IoT is making primary substancial impacts within this industry. With wearable and implantable

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devices, patients vitals can be continuously monitored. This real-time monitoring of patient vitals puts patients at the center of their well being. It allows proactive interventional, especially in the management of chronic conditions [40]. More importantly, patients become greatly involved within the health decision making process, enabling them to tailor data driven insights into their well being.

2. Real-Time Patient Monitoring: As the healthcare sector integrates the Internet of Things, it represents a leap forward that is bound to change how we monitor patients. Kairos Managing Principal William A. J. E. G. Meier states that IoT is making one big difference, and that difference is in patient care. These IoT-enabled wearable sensors and implantable devices are able to monitor important biometrics continuously. This new method of care goes well beyond simply improving patient care: interventions can be undertaken early, particularly with chronic illnesses [40]. Data can support patients' health choices while giving them a more engaging and informed approach to taking care of themselves.

   Figure (2) illustrates how the IoT enables patient monitoring beyond clinic and hospital settings [41]. This is very important in remote or less accessible regions of the world with limited access to health services. Measurement of vital parameters and medication compliance, for example, arms people with the ability to take charge of their health no matter where they live.

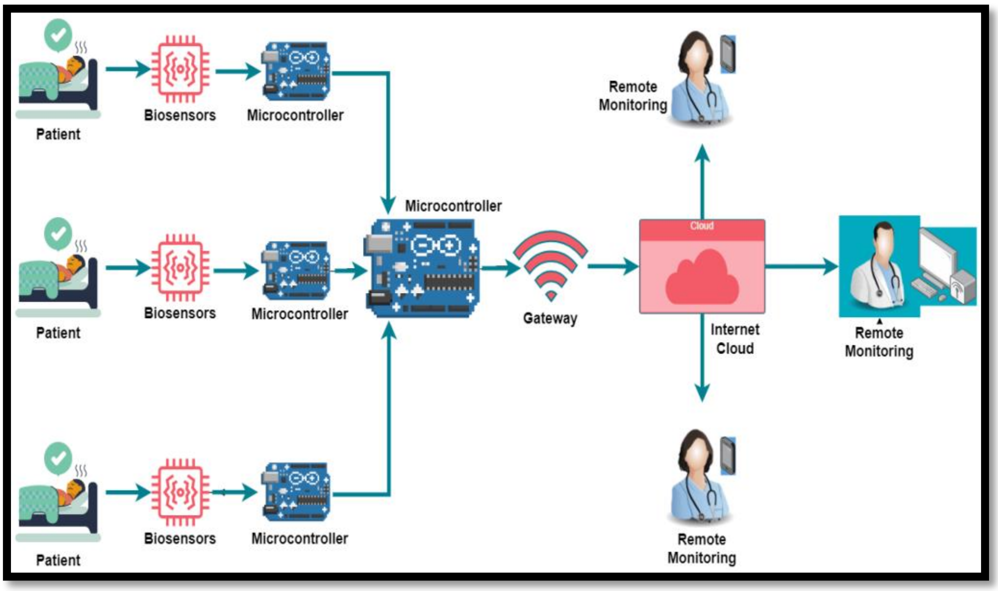

Figure2. Remote monitoring via IoT healthcare systems [42].

3. Telemedicine & Virtual Care: These tools allow patients to speak with health professionals via video calls, chatbots, or mobile applications, which minimises in-person visits while increasing medical access [43-44]. Telemedicine is especially useful in the treatment of chronic conditions, where regular monitoring, timely interventions, and mental treatment support are needed. Telemedicine gained popularity in the COVID-19 period since it provided a better solution for maintaining medical services with a lower possibility of virus spread. Virtual care is also enriched with advanced options such as AI-powered symptom-checking tools and remote monitoring devices that deliver real-time information and customised suggestions. However, the digital divide and internet connection, along with privacy concerns, need to be solved so that everyone has equal access to these programs.

4. Smart Hospital Systems: Patient's vitals can be monitored continuously with the use of IoT devices. These smart devices notify health professionals in case of abnormalities which require timely interventions. AI-enabled predictive analytics are also used to project probable patient admission, resource allocation, and decision-making levels. Despite their potential, challenges such as high implementation costs, data security concerns, and the need for staff training must be addressed to realise the full benefits of smart hospital systems.

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Moreover, robotic process automation (RPA) technology can increase the efficiency of administrative work such as scheduling and managing inventories [45]. Smart hospital systems use advanced technologies to help providers and patients better communicate throughout the entire healing process because these systems give them the power to create custom treatment schedules for each patient

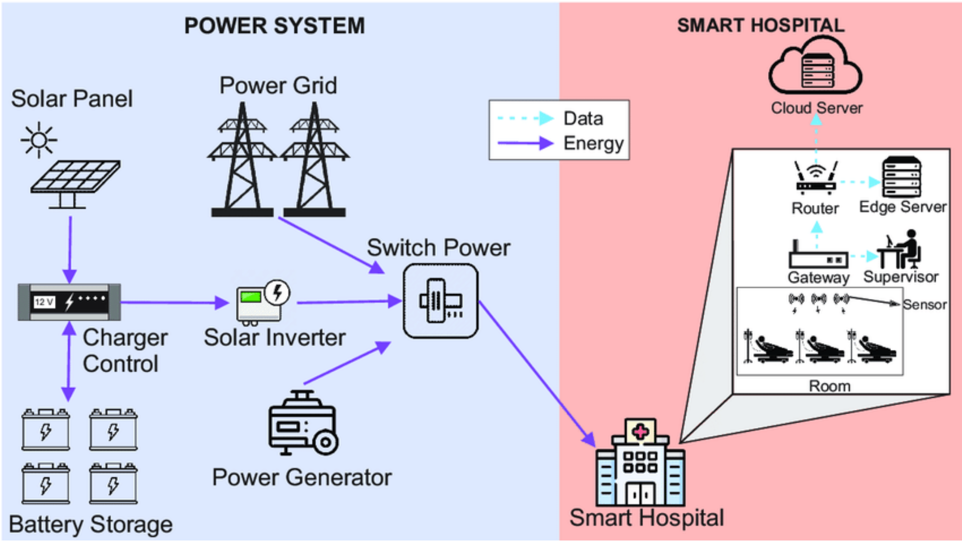

Figure 3.The proposed architecture of a smart hospital system. [45]

5. Predictive Analytics and Disease Prevention: IoNS uses data collection and analysis from different sources to make predictions about disease outbreaks and recommend health strategies. These AI analytics systems analyse information obtained from environmental sensors, electronic health records, and even social media to ascertain trends and risk factors [46-47].
6. Medication management: the use of IoT connections to remind patients of medication at the appropriate time and track their adherence in real-time. Mobile apps offer medication schedules, reminders, and other materials so that patients learn what the prescriptions are for. Healthcare workers can preemptively act when AI systems detect prescription misuse and automatically scrutinise patient information, looking for combinations that do not interact, dosage amounts, and adherence struggles [48]. Furthermore, communication between pharmacists and physicians, as well as patients, is made easier, more accurate, and better coordinated when EHRs are connected to the medication management system. This system is useful for patients suffering from chronic diseases such as chronic diabetes and hypertension, as they need to be treated with medications consistently [49]. However, these systems could face challenges such as the risk of breaching data privacy, incorporation into societies with less access to technology, and complicated user interfaces. These developments contribute not only to the enhancement of medicine management systems but also to the improvement of healthcare service delivery, patient health results, and the workload of healthcare workers.

4. ROLE OF NETWORK SYSTEMS-BASED HEALTHCARE

Network systems-based healthcare, which integrates technologies such as the Internet of Things (IoT), cloud computing, and telecommunication networks, offers numerous benefits that are transforming the healthcare industry. Below is a detailed exploration of these benefits:

A. Improved Patient Outcomes

Patients' smart medical devices and wearable sensors, which are connected through the Internet of Things (IoT), track vital parameters like heart rates, blood pressure, and glucose levels in real-time [50]. This technology makes it possible for healthcare practitioners to notice changes early and take preemptive action if necessary. For instance, patients suffering from chronic illnesses such as diabetes and heart disease are more susceptible to changing health indicators, so remote monitoring systems could bring great advantages to these patients by warning healthcare

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providers before conditions worsen, which can lead to further complications and hospital care. AI-driven data analytic treatment plans ensure that care is caught and that severe conditions that require extensive medical attention are avoided. Furthermore, this makes sure that referred patients do not miss the follow-up appointment. Network systems, on the other hand, extend the range of communications, allowing patients to ask questions and receive timely assistance from their care providers. The adoption of these innovative systems improves the early recognition of health problems, active participation of patients, and individualised treatment greatly enhances health outcomes like morbidity and mortality while improving overall life satisfaction.

B. Enhanced Access to Care

Powered by computer and connecting technologies, telemedicine platforms allow patients to contact healthcare practitioners through video calls, chatbots, or mobile applications, thus eliminating long-distance travel and decreasing access limitations to care. This technology has special significance for patients who have limited or no access to specialist healthcare providers and healthcare facilities, as they are able to get timely diagnoses, treatment, and follow-up care procedures done without leaving the comfort of their homes [51]. Patients in rural areas can access mental health services or chronic disease management programs without the logistical challenges of visiting a clinic. Additionally, network systems support the 24/7 availability of healthcare services, ensuring that patients can receive care whenever they need it [52]. By breaking down geographical and temporal barriers, network systems-based healthcare democratises access to quality care, improves health equity, and ensures that more individuals can benefit from timely and effective medical interventions.

C. Operational Efficiency

By integrating IoT devices, cloud computing, and data analytics, healthcare organisations can automate routine tasks such as patient scheduling, inventory management, and medication dispensing, freeing up staff to focus on patient care [53]. Smart hospital systems use sensors and AI to monitor bed availability and equipment usage in real-time, ensuring optimal resource utilisation and reducing wait times. Predictive analytics help hospitals forecast patient admission rates and allocate staff and resources accordingly, minimising bottlenecks and improving service delivery. Moreover, sophisticated EHRs connected to networks permit better coordination of patient management through shared information access among different departments, which reduces the number of mistakes committed [54]. These changes will not only enhance the quality of health care but also reduce expenditure, making the provision of healthcare more viable and efficient for patient demands. In summary, network-enabled systems in health care resulting in changes in business processes open opportunities for healthcare institutions and practices to provide services faster, more efficiently and of higher quality.

D. Cost Reduction

Cost-cutting can be achieved through the use of IoT tools, telemedicine, and even data analytics in healthcare organisations for monitoring using healthcare technologies. RPM systems, through monitoring equipment, render frequent consultations with a practitioner unnecessary, and so do in-person visits to hospitals. Such practices enhance savings on healthcare costs, such as transport hospitalisation, and place less stress on medical facilities. With telemedicine, virtual provider consultations replace patient office visits, which are usually pricier than checkups over video calls, especially for routine follow-ups and management of chronic illnesses. Additionally, predictive analytics help identify high-risk patients early, allowing timely interventions that prevent complications and readmissions.

Furthermore, much administrative work has been done, and automation such as scheduling and inventory management have reduced efficiency task costs. The effectiveness of the network systems in healthcare is evident as they lower the costs incurred by patients and providers while increasing efficiency, improving resource allocation, and preventing avoidable costs. This improves the affordability and sustainability of healthcare.

E. Public Health Improvement

Using the Internet of Things (IoT), one can now gather data from a plethora of sources in the public health sector, including wearable sensors, electronic health records, and environmental health monitors. This helps public health practitioners monitor the spread of infection alongside environmental health issues [57]. During the COVID-19 pandemic, IoT systems effectively monitored resource allocation, efficiently predicted quarantine hotspots, and

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compliance with quarantines [58]. Network systems can strategically disseminate information, monitor campaign slogan penetration, and manage other efforts toward health promotion. With advanced analytics coupled with AI-powered models, patterns of disease spread and prediction of outbreaks will now be a norm for efficient mitigation.

F. Patient Empowerment

Continuous feedback provided by wearable gadgets, sensors, and mobile health applications facilitates patients' self-management of vitals, physical activities, and medications, thus ensuring a greater feeling of accountability [59]. A diabetes patient can monitor blood glucose levels using a glucose meter attached to a smartphone application, which tracks diet and exercise levels to give tailored suggestions. Digital platforms also comprise educational materials, as well as virtual support groups, which assist patients in making decisions regarding their health. In enabling patients to access their medical history and self-manage their health, network systems-based health care promotes self-determination, which ultimately leads to better treatment compliance, as well as general health. Such a transformation invested in improving healthcare relations aids health outcomes. Further, it fosters a collaborative relationship between patients and providers, yielding a more efficient healthcare system.

G. Improved Communication and Collaboration

Electronic health records (EHR) and internet-based systems allow healthcare providers real-time access to patient information, which enables doctors, nurses, and specialists to make informed decisions [60]. A secure network enables a primary care physician and a cardiologist to remotely access each other's progress notes, enabling more collaborative treatment management of patients. Communication is also greatly improved with the advent of telemedicine, allowing for remote medical consultations and multi-disciplinary team meetings that span different geographical locations. Improved communication also allows for better patient outcomes as patients are able to view their records, receive essential information, and interact with their health providers [61]. Network systems-based healthcare improves coordination of care, communication, and collaboration by automatically destroying silos, lowering medical errors, and ensuring a more holistic approach to treatment.

H. Scalability and Flexibility

Some network systems based on cloud computing and IoT are in a position to keep pace with an increase in patient population, improvements in technologies, or even new healthcare problems. For example, during the COVID-19 pandemic, hospitals had to massively increase their telehealth capabilities to meet the enhanced virtual care needs. These systems are fully adaptable and make it possible to manage specific circumstances like chronic disease management, elderly care, or even public health surveillance. They are capable of configuring to meet the optimally designed workflows of small clinics to large hospital networks, thereby enhancing the productivity of healthcare systems, incorporating new devices, and using multiple healthcare services. This capability allows healthcare organisations to quickly adapt to pressing needs, enhance service provision, and sustain the quality of care even in more volatile environments.

I. Enhanced Research and Innovation

The expansion of IoT devices, electronic health records (EHR), and centralised cloud systems permit network systems to gather and interpret vast volumes of data by identifying and understanding their interrelationships — all of which facilitate medical inventions [63]. AI-based programs can utilise patient information to track changes in disease over time, forecast the effectiveness of a treatment, and integrate the information towards the design of suitable therapies. Network systems enable remote participation in clinical trials, which broadens the availability of studies to novel treatments and enhances the inclusiveness of the study's participants. Also, these interfaces make it possible for academic researchers, health practitioners, and technology developers to combine their skills towards advancing knowledge and resources in a specific area of interest and thus accelerate the level of innovation. The integration of network systems in health care will transform medical research into a data and collaboration-driven process, resulting in enhanced innovation and new achievements in medicine.

J. Sustainability

Smart hospital systems, enabled by IoT, automatically manage lighting, heating, and cooling when real-time occupancy and usage data is available. This proactively reduces energy usage, which saves costs and lowers carbon emissions. Other network systems enhance inventory control, which increases the efficiency of using medical supplies

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while minimising waste. Moreover, the increase in using digital platforms such as electronic health records (EHRs) and telemedicine results in less reliance on paper records and infrastructure, lending further support to environmental sustainability. The reduction of resource use while improving operational efficiency means that network systems-based healthcare is more ideal in the context of gentler and more sustainable endeavours in global healthcare.

5. NETWORK-BASED INTERVENTIONS IN LOW-RESOURCE SETTINGS

Network-based interventions are unique in that they are needed and have worked quite well in resource-poor places, owing to the fact that they require very little healthcare infrastructure. These interventions harness already existing social networks to share and disseminate the required health information and even promote behavioural changes.

The widespread dissemination and implementation of evidence-based programs (EBPs) in community settings has great potential to improve population health outcomes and mitigate health disparities. Community-based organisations (CBOs) can be more effectively leveraged for health promotion, including organisations working with the underserved, which are an important channel for reaching vulnerable populations [66-67].

Peer education programs, for instance, have proven effective in sub-Saharan Africa, where communities are taught by influential local members in order to increase HIV testing rates and condom use. Similarly, CHW activities have shown to be effective in maternal and child health improvement, as is the case for many community health worker CHW programs. They involve the use of acceptable locals to facilitate health education. These strategies leverage trust and reciprocity that are present in social networks, making them useful in places where resources are scarce.

These peer education initiatives are, however, network-based interventions that are nearly always set up in low-resource areas using existing authoritative structures as a point of entry. The main target group of these programs, who are often social acquaintances of the target audience, are trained to pass the correct and appropriate health and health-related information and consumer behaviour information. For example, studies in sub-Saharan Africa show that the presence of peer educators has increased HIV testing and condom use while decreasing stigma towards HIV/AIDS.

These programs are capable of addressing cultural barriers to health intervention targets by facilitating the intervention through trusted and culturally appropriate individuals within the communities. In addition, peer educators facilitate discussions and promote 'safe havens' where sensitive issues regarding health can be discussed without stigma. Peer interventions have been effective even in vulnerable populations such as teens and sex workers who do not seek traditional health care services. Most importantly, the success of these programs depends on the utilisation of social networks. They offer a low-cost and widely applicable solution to health promotion in areas with limited resources.

6. CHALLENGES AND LIMITATIONS

Despite its advantages for public health, the implementation of new network systems and internet technologies has challenges. These issues will be examined in more detail [68-71]:

1. Data Privacy and Security: Collecting, storing, and transmitting sensitive health data can lead to significant privacy and security issues. Patient confidentiality and trust people place in medical facilities may be compromised by unauthorised access, cyberattacks, or malicious data breaches.

2. Digital Divide: There is a gap in access to technology and the internet, which negatively affects health for those in underserved, low-income areas, people living in rural areas, and older people.

3. Interoperability Problems: The absence of generic standards for devices and systems, as well as the capability to communicate between them, highly restricts the sharing as well as integration of information.

4. Quality Issues and Misinformation: False information dissemination at breakneck speed within social spaces can get in the way of public health initiatives, and at the same time, substandard data can compromise the overall analyses and decisions undertaken.

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5. Cost of Implementation: In low-resource settings, healthcare organisations find it difficult to cope with the cost associated with the basic setup, devices, infrastructure, and specialised education required to initiate practice.

6. Ethical Issues: The suspected bias during the employment of AI and automation in healthcare draws ethical concerns around accountability and the potential redundancy of jobs related to healthcare.

7. Reluctance to embrace change: Lack of exposure/trust or unfamiliarity concerning new technological advances within healthcare for both patients and providers may cause them to resist the change.

8. Legal and Regulatory Issues: The complexity of legal requirements and regulations sometimes comes in the way of implementing network systems and internet technologies.

8. CONCLUSION

The expansion of social networks has been influential in promoting health behaviour change by aiding in information exchange, encouragement, and behaviour imitation. Social media and interpersonal networks affect people with regard to peer expectations (norms), group responsibility, and social motivation that help with positive changes like stopping smoking or becoming more active. However, these networks can equally strengthen negative behaviour in the existence of negative influences. Health-related behaviours are prominently practised via digital platforms, which are easier to establish and use on a larger scale. However, there are problems, such as prevention of misinformation and equitable health access, which require elaborate attention. A wide range of directions is now available as long as the weaknesses of social networks are taken into account. By understanding the factors that motivate and encourage the formation of social relationships, effective interventions can make it easier to change health behaviours into enduring ones which will benefit the individual's health as well as the community's health.

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