A Novel Model of Multi-level Linkage Health Management in "Hospital-community-home-individual" in the Era of Internet of Things

Jian Wang, Hongyan Wei, Xin Lan, Xiaohong Li*
Health Management Center, Affliated Hospital of Southwest Medical University, Luzhou, Sichuan, China
**Corresponding Author.*

Abstract: This paper aims to explore the construction of the Internet of Things (IoT) enabled "Hospital-community-home-individual" multi-level linkage health management model. By establishing a framework for constructing the health management model, a combination of theoretical research and practical exploration is utilized to integrate the resources and advantages of hospitals and communities. Hierarchical and graded health management approaches and measures are investigated. The proposed framework for health management model construction in this study can be effectively applied to model development, demonstrating the feasibility of multi-level linkage health management. It provides a reference for the development of IoT-enabled health management models.

Keywords: Methodology; Internet of THINGS (IoT); Hospital-Community-Home-Individual; Multi-level linkage; Health management model

1. Introduction

Building upon the advantages of IoT-enabled remote management and drawing inspiration from the hierarchical and graded diagnosis and treatment approach of "Hospital-Community", this study integrates multidisciplinary health resources with health management at its core. It explores the construction of a multi-level linkage IoT-enabled health management model that encompasses "Hospital-Community-Home-Individual" and emphasizes collaboration among different healthcare professionals. This research provides a reference for the development of a comprehensive health management model for the promotion of national health [1,2].

2. Theoretical Framework for Constructing a Health Management Model

The construction of a health management model involves the organic integration of health management resources and social technological resources, leading to the development of practical activities encompassing health management processes, content, and methods. Currently, both domestic and international model constructions heavily rely on empirical methods and practice-based modifications, lacking a replicable and operational framework for constructing health management models. This limitation hampers the quality of model exploration or construction endeavors. This paper proposes the following framework for constructing a health management model [3]:

Research Team: Form a team consisting of individuals involved in model construction research, model operation and exploration, and data organization and analysis .

Information Collection: Gather relevant information through literature research, policy analysis, interviews, or field investigations, summarizing elements, content, processes, and regulations related to health management models.

Ideation: During this stage, the team typically employs brainstorming and SCAMPER techniques (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Rearrange) to generate various possible health management models, encouraging creative divergence.

Prototyping: Use methods such as group discussions and expert consultations to select the most feasible health management

model proposal and engage in discussions and refinements to construct the prototype of the health management model [4].

Empirical Iteration: Implement and run the prototype, continuously improving the health management model based on practical discoveries, problems, and feedback. This aims to enhance the practicability, collaborative capability, and feasibility of the model.

Based on the aforementioned framework for constructing a health management model, a research team was assembled, consisting of experts in hospital health management, doctors, technicians, and community health management doctors and technicians. An investigation into the current status of community health management was conducted, resulting in the development of a prototype for a novel IoT-enabled "Hospital-Community-Home-Individual" multi-level linkage health management model. The prototype includes elements such as grid-based governance, advanced health management technologies, optimized workflows, and targeted population classification. Through an iterative process of practical implementation and improvement, the model continues to evolve and enhance its practicality[5,6].

3. Current Status of Community Health Management

Through field investigations and interviews conducted in Luzhou City, the current state of community health management can be summarized as follows: The main focus is on comprehensive preventive care led by the Community Health Service Center; health management is based on the distinctive comprehensive preventive care system in Luzhou City; residents' health records are established according to standardized protocols; regular health check-ups are scheduled for residents; a tiered follow-up and health education system is implemented based on residents' health conditions; and regular home visits are conducted by family doctors [7].

However, there are several deficiencies and challenges in the current health management system: Lack of intervention management, insufficient real-time monitoring of health data, relatively simplistic health record information, underdeveloped online models for health education and guidance, absence of dynamic early warning mechanisms, inadequate health literacy, low compliance, and low utilization rates of health apps and devices.

4. IoT-Enabled "Hospital-Community-Home-Individual" Multi-Level Linkage Health Management

4.1 Grid-based Framework

The grid-based health management framework divides healthcare service resources, personnel, and service recipients into smaller grids for effective management, thereby improving the precision and comprehensiveness of healthcare services. As illustrated in Figure 1, the hospital level serves as the center for health management, integrating various specialty resources and extending its reach to multiple community grids through health information sharing and remote management. The integration of community health management application bases with the community enables the establishment of health records, follow-ups, health education, and management for community residents in a tiered manner. Online platforms are utilized to facilitate dietary, exercise, medication management, and health indicator monitoring, promoting self-management of health in a home-based setting.

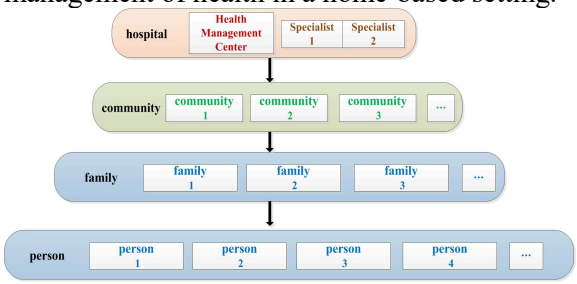

Figure 1. Grid-based Health Management Framework

4.2 IoT-enabled Health Management Software Platform

In this model, a multi-level linkage IoT-enabled health management platform with independent intellectual property has been developed, including the hospital-end, community-end, and client-end. This platform integrates physical examination data and hospitalization data, facilitates the establishment of health records, automatically categorizes population groups, enables the transmission of data from client-end devices to management systems, allows data uploads from client-end devices,

facilitates the formulation of health plans, and supports health management follow-ups.

4.3 5G-enabled Health Management Technology

Based on 5G technology, effective empowerment of community health management applications for residents' home-based health management, guidance, and monitoring can be achieved. The developed 5G-enabled health management technology includes 5G-enabled remote exercise management, 5G-enabled nutrition management, 5G-enabled remote monitoring, 5G-enabled remote high-definition teaching, and 5G-enabled remote health cabin.

5G-enabled remote exercise and nutrition management refer to providing residents with scientific guidance on exercise and diet through the 5G network, implementing dynamic monitoring of exercise data, and issuing exercise risk warnings.

5G-enabled remote monitoring refers to the combination of 5G network and home health monitoring devices (refer to Figure 2), such as blood glucometers, blood pressure monitors, sleep trackers, body fat scales, and smart bracelets. These devices dynamically monitor clients' home health data in real-time, achieving precise monitoring and intelligent early warnings. The monitoring records are provided to healthcare management personnel at all levels, making health management simpler, more convenient, and efficient[8].

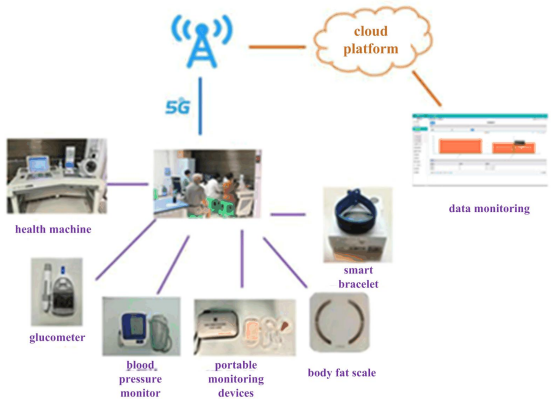

Figure 2. 5G-enabled Home Monitoring

5G-enabled remote high-definition teaching refers to utilizing 5G technology to provide remote guidance from hospitals or communities, making remote video guidance more convenient and facilitating the allocation of high-quality health management resources.

5G-enabled health cabin involves equipping the community health management application base with a health management platform, health integrated machines, remote video environment, and 5G network environment. It realizes online and offline health management services for community residents.

4.4 Process and Content of 5G-enabled Health Management

The IoT-enabled "Hospital-Community-Home-Individual" multi-level linkage health management model is a comprehensive health management system, with its process illustrated in Figure 3. Under this model, the community health management application base divides community residents into high-risk groups, chronic disease groups, general population, and sub-healthy groups based on health data and population classification standards. Based on this stratification, individuals can receive either 5G-based community health management or the layered health management of "Hospital-Community-Home-Individual" with 5G support.

The layered health management model builds a multi-level and coordinated health management framework, primarily consisting of three main components: remote home management, routine community management, and comprehensive hospital management. Among them, the combination of home and community forms 5G community health management, while the integration of hospital, community, and home creates the 5G-enabled layered "Hospital-Community-Home-Individual" health management.

The remote home management leverages 5G technology and wearable devices to enable remote monitoring of residents' health indicators, including data on blood pressure, blood glucose, weight, exercise, and nutrition. By using 5G wearable devices at home and uploading data, health management personnel are able to constantly track the health status of patients. In cases of abnormalities, the system will automatically issue alerts, allowing managers to provide online guidance and

remote interventions.

Routine community management entails regular monitoring, education, and personalized guidance. Regular monitoring covers the tracking of important health indicators such as body mass index, blood pressure, and blood glucose. Educational activities encompass various aspects including diet, exercise, and mental health. Finally, based on individuals' basic information and routine data, personalized guidance and regular follow-ups form a closed-loop health management process. If complex health issues are detected during this process, patients will be guided to the next component.

Comprehensive hospital management is the highest level of this model, dedicated to addressing complex and perplexing health issues. It provides precise and comprehensive health management services, including in-depth examinations, evaluations, psychological assessments, exercise assessments and management, nutrition assessments and management, multidisciplinary consultations, and more. At this stage, personalized and accurate evaluations and management of exercise and nutrition are conducted. Moreover, through the utilization of 5G technology, hospitals can offer remote teaching and MDT joint consultations, enabling online guidance and interventions. Individuals involved in this health management model can receive a combination of online and offline guidance. During the process of remote home management, they upload data through diet check-ins and exercise apps, allowing hospital and community managers to provide online guidance and remote interventions, including MDT joint consultations, while also utilizing automatic warning systems for exercise intensity risks. Managers can also provide offline guidance and follow-ups in the community or hospital settings.

The 5G "Hospital-Community-Home-Individual" hierarchical health management model combines a multidisciplinary health management team and a smart health hierarchical management platform to achieve precise hierarchical assessment management, dynamic monitoring, follow-up, and personalized adjustment programs, forming a closed-loop management system.

The IoT-based health management services include establishing health records, collecting health data, providing health guidance, implementing precise interventions, evaluating the effectiveness, and conducting regular follow-ups. Here are more specific details:

Establishing health records: This includes basic information, historical health records, physical examinations, laboratory tests, outpatient records, and hospital records of residents.

Health data collection: Residents use 5G smart devices at home or in community health cabins to monitor and collect various physiological data, including body temperature, BMI, blood pressure, blood glucose (fasting, postprandial), and blood oxygen levels. This data is uploaded to the platform via Bluetooth and presented in the form of trend charts. Based on the residents' basic information, professional doctors regularly develop personalized monitoring plans and conduct centralized monitoring.

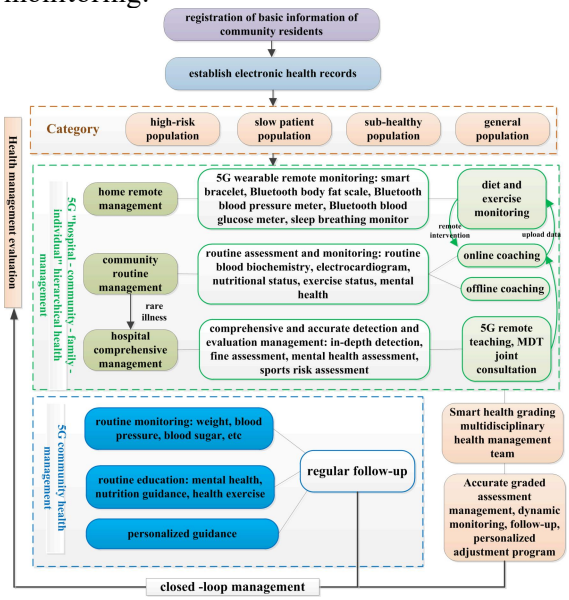

Figure 3. IoT-based Multi-level Linkage Health Management Process

Health guidance: The establishment of health guidance sets overall objectives, such as setting intervention goals for patients with hypertension: ensuring stable and standardized physiological data control (including blood pressure), slowing down the progression of hypertension, preventing complications and avoiding sudden risks. It

also entails adopting a scientific and healthy lifestyle, developing a comprehensive understanding of hypertension, cooperating with doctors to address disease prevention and control, and acquiring basic knowledge and self-lifestyle intervention methods for managing hypertension. Health guidance includes medication guidance, dietary guidance, nutrition guidance, exercise guidance, psychological guidance, correction of unhealthy behaviors, health preservation and care, disease education, and regular monitoring of routine indicators. Health managers or community doctors develop corresponding health guidance plans based on the residents' health assessment results for different categories, aiming for precise interventions.

Precision intervention: As mentioned earlier, for the corresponding health guidance, health managers or community doctors develop personalized and precise intervention plans for graded management of residents in different categories. Specific medication treatment plans are formulated by professional physicians, while health managers provide specific dietary guidance plans (such as balanced diet, daily intake, food choices, low sodium, high potassium, low fat, calcium supplementation, cooking methods, etc.) at designated times. Additionally, exercise guidance plans (safety, moderation, intensity, methods, etc.) and lifestyle behavior interventions (sleep, hydration, smoking, alcohol consumption, etc.) are provided. Routine indicator monitoring is conducted according to the monitoring plan and warning range. In general, physicians determine the periodic update of intervention plans.

Evaluation of effectiveness: Health management assessment is conducted through key data comparison, such as comparing blood pressure and blood glucose levels before and after intervention, in conjunction with clinical diagnosis, examinations, and medication treatment. The implementation of health management is evaluated through follow-up assessments.

Regular follow-up: Health managers conduct intervention follow-ups on residents through the client-side platform, sending intervention contents and receiving feedback on residents' actions. Follow-ups are conducted regularly based on the follow-up requirements outlined in the population classification criteria. After each follow-up, follow-up records are perfected, with data sourced from the follow-up record form, including vital signs, lifestyle, and medication.

4.5 Population Classification and Management Standards

In this model, the classification of populations is based on the grading criteria outlined in the *National Norms for Chronic Disease Prevention and Control (Trial)*[9]. Populations are divided into the general population, chronic high-risk population, chronic disease population, and sub-healthy population.

For the chronic high-risk population, the community is required to conduct two annual follow-ups, providing guidance on healthy lifestyles and monitoring high-risk factors or disease indicators (monitoring contents: blood pressure, blood lipids, blood glucose, uric acid, waist circumference, BMI, smoking). Special emphasis should be placed on health interventions for individuals with impaired blood glucose regulation.

For key populations within the chronic disease population, the community needs to conduct four annual follow-ups, monitoring blood pressure, blood lipids, blood glucose, uric acid, waist circumference, BMI, and smoking status. For the targeted populations, the community should request them to fill out follow-up registration forms for primary hypertension and type 2 diabetes patients, with at least four times per year.

For the sub-healthy population, the community needs to provide health education lectures and guidance based on individual needs.

5. Evaluation of the Model

5.1 Practice Exploration

The IoT-enabled "Hospital-Community-Home-Individual" multi-level linkage health management model, as a forward-thinking approach to health management, has shown significant achievements in its implementation. To date, a total of 104 participants have established personal health records and received 153 health management services.

These participants are divided into four main groups: the general population (21 individuals), chronic high-risk population (32 individuals), chronic disease population (148 individuals), and sub-healthy population (13 individuals). Based on this classification, we have employed different management strategies to provide personalized health services for each group. The general population has received 5G community health management, while the chronic high-risk population, chronic disease population, and sub-healthy population have benefited from the 5G "Hospital-Community-Home-Individual" multi-level linkage health management approach.

In order to assess the effectiveness of this model, interviews were conducted with participants including health managers from hospitals and communities, as well as community residents. The findings indicate that community residents involved in this model have demonstrated significant improvements in health literacy, self-management abilities, and health behaviors when compared to traditional management approaches. These improvements are also reflected in the control of blood pressure and blood glucose levels. Furthermore, a portion of residents with chronic diseases or a high chronic disease risk have experienced improvements in their health status after being managed under this model, resulting in a reclassification of the population.

The IoT-enabled multi-level linkage health management model operates organically between hospitals, communities, homes, and individuals, significantly enhancing the efficiency and quality of health management. Firstly, this model breaks down geographical barriers between hospitals and community services. This facilitates the transfer of high-quality health management resources from hospitals to communities, providing high-quality health management services to community residents in need and establishing a green channel from the community to the hospital. Secondly, the model surpasses the limitations of time and space in health monitoring and guidance. It enables real-time monitoring of health indicators, opening up possibilities for remote health consultation and guidance, allowing community residents to conveniently manage their health[10].

In addition, the IoT-enabled multi-level linkage health management model has also created numerous new healthcare service positions, such as health management specialists and health management physicians. This promotes employment in the field of health management and makes a positive contribution to the socio-economic development.

5.2 Value in Research and Education

The IoT-enabled "Hospital-Community-Home-Individual" multi-level linkage health management model holds significant importance in the fields of research and education, as outlined below:

Encouraging innovation in health management education: This model provides an innovative teaching platform for our university to cultivate health management professionals with skills aligned with the IoT era. It emphasizes holistic health management across hospitals, communities, homes, and individuals, aiming to develop students with comprehensive knowledge, skills, and collaborative abilities in IoT-enabled health management. This better equips them to adapt to future health management environments.

Facilitating interdisciplinary research: The model offers a research platform for IoT-enabled health management studies. Its multi-level linkage structure encourages collaboration among experts from diverse fields, stimulating the need for interdisciplinary research in medicine, engineering, information technology, social sciences, and more. This broadens the research scope, promotes the development of technical systems, and contributes to addressing complex challenges posed by chronic diseases.

5.3 Innovativeness and Promotional Value of the Model

The model presented in this paper showcases several noteworthy innovations that offer valuable insights for future health management. Firstly, we have integrated data from regular check-ups, follow-up examinations, and wearable devices. This comprehensive data integration enables efficient monitoring of layered and dynamic health data, resulting in a significant improvement compared to the traditional static records. Secondly, we have effectively combined the dual resources of "hospital-community" and incorporated them

into the content of health management, achieving a multi-level and interconnected approach to layered health management. This model follows a closed-loop process of "information collection - assessment - personalized plan formulation - dynamic monitoring and management", leveraging the advantages of IoT technology in health management. Most importantly, this model holds the potential to address the isolated nature of traditional hospital and community-based health management methods and bring about improvement in this regard.

The research focuses on establishing a multi-level and interconnected health management system, which has facilitated the development of various 5G-enabled health management technologies. These include 5G-based remote sports management, 5G-enabled nutrition management, 5G-enabled remote monitoring, and 5G-enabled remote high-definition instruction. Furthermore, a 5G-enabled health management process, content, and standards have been formulated, along with two health management models: 5G community health management and the layered health management model of "hospital-community-home-individual" enabled by 5G. Additionally, a smart health management platform applicable to multi-level health management has been developed. Collaboration with a specific community has led to the establishment of a demonstration unit for application. This system possesses replicability and scalability, and can be directly applied to other communities, as well as extended to corporate and institutional health management.

This health management model is beneficial in promoting the development of new health services in the fields of IoT-based health monitoring, screening, risk assessment, and intervention. It also contributes to the growth of the health economy and the incubation of new employment opportunities. The replication and promotion of this system are advantageous for chronic disease prevention and control, reduction of medical costs, enhancement of public health literacy, and improvement of self-management capabilities.

6. Challenges and Corresponding Strategies

The establishment of a multi-level linkage health management model faces various challenges in practical exploration, including health data silos, data privacy and security, low internet proficiency among the elderly, profitability issues, talent shortages, and multi-agent resource integration. The following is a detailed discussion of these challenges and corresponding strategies:

Constraint of health data silos: Data isolation leads to inefficient health information sharing, diminishing the accuracy and efficiency of health management decisions. Establishing data standards and interoperability protocols are vital to enable seamless data exchange between different healthcare systems. Embracing distributed ledger technologies, such as blockchain, ensures the security and traceability of the data.

Data privacy and security: The potential leakage and misuse of health data pose a threat to patient privacy and undermine trust. It is essential to establish stringent data privacy regulations that clearly define rules for data collection and usage. Strengthening data encryption, identity authentication, and access control measures should be implemented to safeguard the privacy of health managers.

The low internet and smart electronic device penetration among elderly individuals in the community poses difficulties for the widespread adoption of a multi-level linkage health management model. Promoting training programs for smart devices, enhancing digital literacy among the elderly, and designing user-friendly interfaces with simplified operational processes are essential to lower the barriers to usage.

Profitability challenges in the short term for the health management model: The initial investment required for a multi-level linkage health management model makes it challenging to achieve significant profitability in the short term. Developing a long-term strategic plan to attract investors' attention to the long-term potential of the health management field, seeking government support and partnerships, will ensure steady development.

Difficulty in addressing the talent shortage in health management services: Cultivating and attracting highly skilled health management professionals poses a significant challenge. Establishing

dedicated programs and courses for health management, creating pathways for professional recognition in the health services and management field, and expanding health management training initiatives are vital in attracting and cultivating exceptional talent. Additionally, strengthening collaborations between universities and research institutions will advance education and research in the field of health management.

The integration of multi-sector resources between hospitals and communities poses challenges for comprehensive health management. The involvement of multiple entities and the dispersion of resources hinder collaboration and integration efforts. To overcome these challenges, it is essential to establish cross-departmental coordination mechanisms that foster collaboration among hospitals, communities, and government agencies. Clear policies and incentive measures should be developed to promote resource integration, such as further optimizing shared health records and information platforms to improve the allocation of information resources.

Based on the above analysis, the following policy recommendations are proposed:

- Formulating unified standards and interoperability regulations for health data, along with funding and support for the construction of health information exchange platforms to ensure data interoperability between different health systems.
- Establishing stringent data privacy regulations that clearly define rules for data collection and usage, in order to protect the privacy rights of patients and users.
- Encouraging institutions at all levels to conduct digital literacy training programs for the elderly, enhancing their familiarity and proficiency with the Internet and smart devices.
- Providing tax incentives or other measures to encourage long-term investment and exploration by relevant entities.
- Promoting the establishment of courses related to health management and establishing smooth channels for professional recognition.
- Establishing a policy-guided fund that enables the government to take the lead in establishing cross-departmental coordination mechanisms to facilitate collaboration among hospitals, communities, and government entities.

7. Conclusions

As a unit supported by the National Health Commission, the Ministry of Industry and Information Technology, and the Provincial Health Commission in the "5G-based Health Management" project, our organization actively engages in the exploration of a replicable, high coverage, and efficient "Hospital-Community-Home-Individual" multi-level linkage health management model empowered by the Internet of Things (IoT). Based on our current practices and experiences in this model, we have innovatively summarized our findings and aim to promote the adoption of this health management service model. Additionally, the effectiveness of this model requires further quantitative empirical research. As such, our research team plans to transform this study outcome into further quantitative empirical research to explore the application effects of various chronic disease management interventions.

Acknowledgments

This paper is supported by Soft Science Research Program of Sichuan Provincial Science and Technology Department (No. 22RKX0663), the Higher Education Teaching Research and Reform Project of Southwest Medical University (No. JG2022007), and Sichuan Province Cadres Health Research (No. 2021-1504).

References

[1] Outline of the "Healthy China 2030" Plan. Chinese Journal of Preventive Medicine, 2019, 20 (08): 770.

[2]. Healthy China Action (2019-2030): General Requirements, Major Actions, and Key Indicators. Chinese Circulation Journal, 2019, 34 (09): 846-858.

[3] He J, Wang T. The community proactive health management model based on the grounded theory: The case of Beijing, China. Heliyon, 2023, 9 (4).

[4] Liao Shengwu, Zhu Hong, Tan Bihui. Challenges and Countermeasures for the Delivery of Internet-based Integrated Medical and Nursing Care for

Community-dwelling Elderly People with Chronic Diseases. Chinese General Practice, 2019 (7): 7.

[5] Bai Shuzhong, Wu Liuxin, Wu Fei, et al. The situation and task of health management in China during the 14th Five Year Plan Period. Chinese Journal of Health Management, 15(1): 4.

[6] Shen H, van der Kleij R, van der Boog P J M, et al. Digital tools/eHealth to support CKD self-management: A qualitative study of perceptions, attitudes and needs of patients and health care professionals in China. International Journal of Medical Informatics, 2022, 165: 104811.

[7] Chen B, Dou Y, Yu X, et al. Influence of Internet-Based Health Management on Control of Clinical Parameters in Patients With Hypertension: Four-Year Longitudinal Study. Journal of Medical Internet Research, 2023, 25: e42896.

[8] Dixit N, Van Sebille Y, Crawford G B, et al. Disparities in telehealth use: How should the supportive care community respond?. Supportive Care in Cancer, 2022: 1-4.

[9] Hu Xiaojiang, Xu Jinshui, Jiang Lun. Manual on Health Management and Practice of National Basic Public Health Services. Southeast University Press, 2020.

[10] Pateraki M, Fysarakis K, Sakkalis V, et al. Biosensors and Internet of Things in smart healthcare applications: challenges and opportunities. Wearable and Implantable Medical Devices, 2020:25-53.

