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REVIEW ARTICLE

The implementation path of intelligent rehabilitation under the background of healthy China construction

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ABSTRACT

The improvement of rehabilitation service capacity is an important part of the construction of a healthy China, and intelligent technology is a powerful means of rehabilitation development. This paper reviews the background of a series of national policies for the construction of a healthy China, analyses and summarizes the many shortcomings that currently restrict the improvement of rehabilitation service capabilities, and proposes the implementation path of intelligent rehabilitation. By expounding the service process of intelligent rehabilitation, and analysing in detail the intelligent technical means suitable for integration from the four key links of real-time health monitoring, remote home intelligent rehabilitation intervention, health classification evaluation standard system and health intervention standard system, the general framework of implementation path of intelligent rehabilitation is built. Taking hypertension rehabilitation as an example, the article introduces the intelligent rehabilitation practice exploration and reference model in three aspects: The research and development of hypertension intelligent equipment, the clinical research of hypertension rehabilitation and the construction of hypertension rehabilitation database. Finally, combined with the concept of intelligent interconnection of all things, the definition of "rehabilitation Internet of things" is proposed, and the time is right for intelligent rehabilitation in the context of building a healthy China.

Keywords: healthy China; rehabilitation; intelligence; wearable; hypertension

1. Introduction

Since the reform and opening up, our country's health undertakings have made new remarkable achievements, the level of medical and health services has been greatly improved, and the main health indicators of residents are generally better than the average level of middle-income and high-income countries[1]. However, factors such as population aging, changes in disease spectrum and in people's attitudes, have put forward new requirements for our country's health service level, and the health service system centred on disease treatment can no longer meet people's health needs[2]. Centring on the construction of a healthy China, rehabilitation has an innate mission in the transformation from patient disease treatment as the centre to people's health promotion as the centre. On November 27, 2020, the Intelligent Rehabilitation Professional Committee of the Chinese Association of Rehabilitation Medicine was officially established

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at the China National Convention Centre[3]. The special committee brings together the top talent resources in rehabilitation medicine and medical engineering in the country committing to building an integrated exchange platform for intelligent rehabilitation and exploring cutting-edge topics in the intersection of artificial intelligence and rehabilitation medicine. The in-depth integration of a series of modern intelligent technologies represented by artificial intelligence, virtual reality, network cloud and wearable sensing with rehabilitation will greatly enrich the means of rehabilitation evaluation and intervention, and make up for the deficiencies of rehabilitation medical services at the current stage.

2. Problems to be solved in rehabilitation in the context of building a healthy China

An aqueous homogeneous mixed salt solution containing $Cu(NO_3)_2{\cdot}3H_2O$ and $Mg(NO_3)_2{\cdot}6H_2O$ was prepared and simultaneously precipitated by drop-wise addition of 10% aqueous K_2CO_3 solution at a pH of 9.0 under constant stirring at room temperature. The resultant mixed Cu-Mg precipitate (precipitate of 10wt% Cu-MgO catalyst, ppt1) has been separated under reduced pressure and washed thoroughly with hot distilled H_2O until the complete removal of potassium ion. In a separate experiment, requisite amount of $Co(NO_3)_2{\cdot}6H_2O$ aqueous solution has been precipitated at a pH of 9 using K_2CO_3 under vigorous stirring. The obtained cobalt precipitate (ppt2) was filtered and washed thoroughly with hot water. Cu-Mg precipitate (ppt1) and Co precipitate (ppt2) were mixed in water under neutral condition and the resultant slurry was subjected to hydrothermal treatment at 373 K for 12 h followed by filtration with repeated washings. The precipitate was dried in oven at 393 K for 12 h followed bycalcination at 723K for 5 h. Similar procedure has been adopted for the preparation of other CoO promoted Cu-MgO catalysts. The catalysts were coded as 1CoO-10Cu-MgO, 5CoO-10Cu-MgO, and 10CoO-10Cu-MgO, here the numericals represents the loadings of Co and Cu by weight percentage. For example, 1CoO-10Cu-MgO represents a catalyst containing 1 wt% Co, 10 wt% Cu and the rsemaining balance MgO. With the decisive battle to build a moderately prosperous society in an all-round way, the party and the country attach great importance to health issues, and lay out a strategic blueprint for the construction of a healthy China in stages: On October 25, 2016, the Central Committee of the Communist Party of China and the State Council promulgated and issued the *"Healthy China 2030" Planning Outline*, setting the headquarters for the construction of a healthy China[4]; On June 24, 2019, the General Office of the State Council issued the *Healthy China Action Organization, Implementation and Assessment Plan*, which clarifies the implementation framework for the construction of a healthy China[5]; on July 15, 2019, the State Council issued the *Opinions on Implementing the Healthy China Action*[6], and the Healthy China Action Promotion Committee issued the *Healthy China Action (2019–2030)*, which detailed the implementation of the healthy China construction[7]. This series of national conferences and documents from top-level design to implementation plan jointly convey the core idea of building a healthy China: To provide fair, accessible, systematic and continuous health services for the entire life cycle for the entire population. Rehabilitation is the comprehensive and coordinated application of medical, social, educational, and occupational measures aimed at maximizing functioning and reducing dysfunction in individuals with health conditions in interaction with their environment influence[8]. Strengthening the construction of the national rehabilitation system is one of the key contents of the construction of a healthy China. Early diagnosis, early treatment and early rehabilitation are essential components to achieve national health. The construction of our country's rehabilitation service system should establish the concept of "big rehabilitation", closely focus on the foothold of the whole population and the whole life cycle, based on community rehabilitation and guided by prevention[9], to provide accessible and affordable rehabilitation services for all.

However, the current rehabilitation service model in my country has many defects, which restrict the realization of comprehensive rehabilitation for the whole people. Summarizing the existing research in my country, there are mainly the following problems: Firstly, the service population is limited and the service stage is lagging behind. Rehabilitation medical resources focus on serving the injured, sick, and disabled. Healthy and sub-healthy people lack the awareness of rehabilitation and access to professional rehabilitation services. Inpatient rehabilitation is widely carried out, but early rehabilitation for many diseases is incomplete[10]. Secondly, the distribution of rehabilitation medical resources is uneven. In our country, the distribution of rehabilitation medical resources in institutions and regions is unbalanced. Large general hospitals are complete but grassroots hospitals are insufficient[11], and economically developed areas are leading and poor areas are lagging behind[12]. Thirdly, the function evaluation index system is not perfect. Lack of a complete functional evaluation index system, so that functional changes are only discovered after the development of functional disorders or diseases, and early warning cannot be used; the time-project-oriented evaluation system and generally low quality of personnel lead to poor problem-solving ability in grass-roots rehabilitation institutions and cannot be trusted by patients[13]. Fourthly, the evaluation and intervention methods are coarsened, and the iterative technology application lags behind. The commonly used rehabilitation evaluation methods are mainly based on qualitative and subjective judgments, and depend on the experience of the operator; the quality of rehabilitation professionals is uneven, and it is difficult to guarantee the homogeneity of rehabilitation and the effect of intervention[14]; the revision of assessment and intervention guidelines is time-consuming and labor-intensive to collect and organize evidence, resulting in a lag in the iterative technology application. Relying on the strength of any unilateral institution such as medical treatment, management or enterprise, it is difficult to solve the above problems in the short term, and new means or models are urgently needed.

3. Implementation path of intelligent rehabilitation

In recent years, technologies such as information, sensing, network and artificial intelligence have developed rapidly, driving the development of intelligent rehabilitation technology. Because intelligent technology has many characteristics such as informatization, networking, data quantification and automation, it has been widely studied and applied in clinical rehabilitation evaluation and intervention at home and abroad[15,18], rehabilitation informatization construction[19] and home rehabilitation[20,21], etc. However, the existing intelligent rehabilitation equipment or systems have relatively simple functions, and the intervention and evaluation focus on the rehabilitation of a certain disease, and the intervention of the whole population and the whole cycle of rehabilitation has not been realized. All kinds of equipment are relatively independent of each other, different equipment manufacturers stand on their own, and there is no unified intelligent rehabilitation technology standard and system. Therefore, it is necessary to propose an intelligent rehabilitation implementation path that systematically integrates various intelligent technologies, so that intelligent rehabilitation can better serve the goal of healthy China.

3.1. Service path

Intelligent rehabilitation should be positioned at the national level, the whole cycle and the homogeneity of rehabilitation. Rehabilitation network sinks into families, so that everyone can enjoy the accessible way of rehabilitation services; real-time health indicator monitoring is carried out, and rehabilitation intervention is moved forward, so that individuals can get rehabilitation intervention in the whole cycle; make high-quality rehabilitation resources reach the grassroots of all parties, and achieve homogenization of rehabilitation services. According to health influencing factors and risk

indicators, it is possible to predict that individuals may or already have certain health problems in the future, classify and evaluate health problems, and give feedback to individuals and families. Provide scientific advice and approaches for individual health problems. For those who need intervention in medical institutions, referral channels are provided; for those who can be intervened at home, remote home intervention is carried out. At the same time, the intervention and health changes of individuals are tracked and recorded throughout the whole process, and daily real-time health monitoring will continue until the end of the round of intervention. see **Figure 1**.

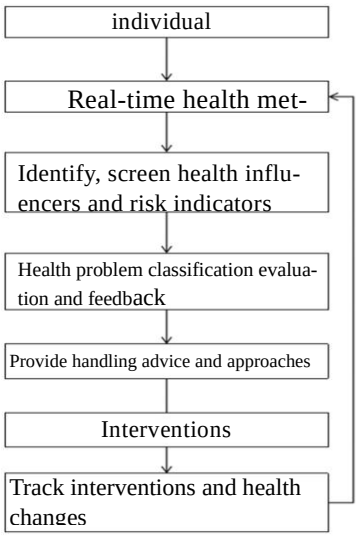

Figure 1. Intelligent rehabilitation service path.

3.2. Technical path

Real-time health monitoring

Based on the theory *of International Classification of Functioning, Disability and Health* (ICF), health status is the interaction between individual body structure and function, activity, participation and living environment[22]. Health monitoring indicators should include: Firstly, physical function and structural indicators such as heart rate, heart rhythm, respiration, blood pressure, balance, and joint activity of individuals; secondly, activities and participation indicators such as exercise, diet, and daily life; thirdly, environmental indicators such as home, travel, and working environment that individuals are exposed to. Wearable sensors are used to monitor individual indicators, and a Bluetooth module is integrated. The sensor data is transmitted to clients through Bluetooth such as smart-phones, and then to the cloud server through the wireless network. Medical institutions and family members can obtain data from the cloud through the network. See **Figure 2** and **Table 1**. **Table 1** lists some applications of wearable sensors in health monitoring. In addition, environmental sensors can also be used to monitor safety, activity, and environmental changes, such as the Oregon Centre for Aging Technology Smart Home and the University of Florida Gator Technology Smart Home[23].

Remote home intelligent rehabilitation intervention

The establishment of a remote home intelligent rehabilitation system is the basis for safe home intelligent rehabilitation intervention. Through short-range communication technologies such as Bluetooth, ZigBee, and WLAN, connect wearable monitoring equipment, smart phones, computers and other terminals, environmental sensing equipment and home rehabilitation intervention equipment, and then with the connection of the Internet, servers and medical institutions establish a remote home intelligent rehabilitation system. Some studies have carried out similar practices, but the target population is relatively limited and the function is relatively single. See **Figure 3**. For example, Li[33] used wireless Bluetooth transmission technology to connect the Biofeedback Therapy Instrument, Physiological Monitor and Host Computer, and with the connection of the server and the hospital through the Internet, designed a remote Home Intelligent Rehabilitation System for neuromuscular injury rehabilitation; Qiu et al.[34] connected the Leap motion controller, computer and cloud server to design a remote Home based Virtual Reality (HoVRS) for the rehabilitation of hand dysfunction after stroke.

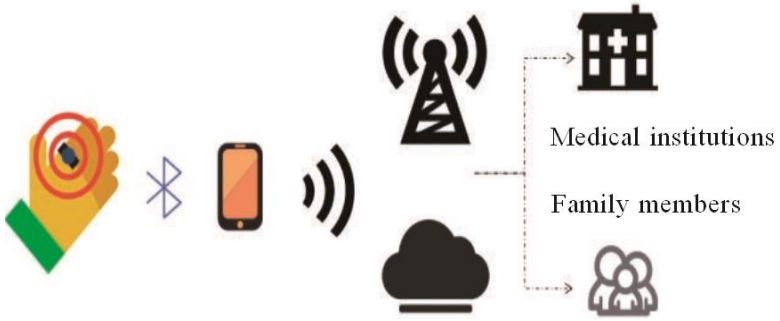

Figure 2. Schematic diagram of remote real-time health monitoring based on wearable devices.

Table 1. Application of wearable sensors in health monitoring

Indicator classification	Wearable sensor type	Application
Body	Photoelectric pulse wave biosensor	Monitor heart rate[24] and blood pressure[25]
	Flexible fabric integrated sensor	Monitor breathing[26]
	Motion capture sensor	Monitor posture[27]
Function and structure	Biochemical sensor	Monitor sweat composition[28]
	Electrochemical sensors	Monitor harmful substances in food[29]
Activities and participation	Chest strap swallowing respiratory sensor	Monitor diet[30]
	Acceleration sensor	Recognize motion[31]
Environment	Air quality sensor	Monitor air quality of individual exposure (ozone, particulate matter, temperature, humidity, etc.)[32]

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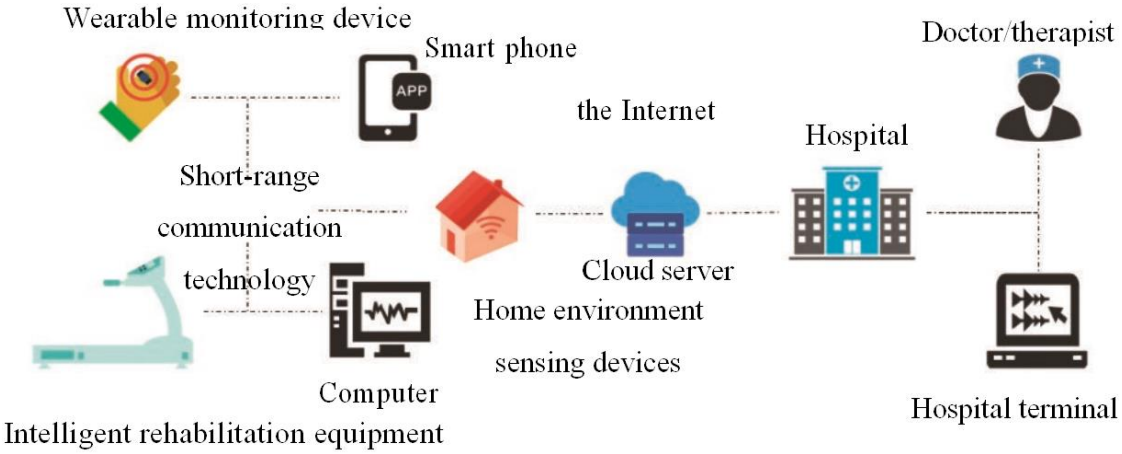

Figure 3. Schematic diagram of remote home intelligent rehabilitation system.

Health classification evaluation standard system

The ICF core classification combination is a list of categories selected from the full ICF framework that are most relevant for assessing and reporting functional information for a specific health condition or health care situation, for assessing the functioning of patients with a specific disease or in a specific health care situation[35]. The ICF core classification combination breaks the traditional scale evaluation thinking, and three-dimensionally describes the individual's health status from the perspective of body structure and function, activity, participation and environment. Using the ICF core classification combination to dynamically evaluate the health status[22,35], the identification results of each index can be converted into standardized ICF limit values according to the ICF framework, and the artificial neural network (ANN) can be used for standardized data analysis, thereby forming a standardized health evaluation method similar to the ICF core classification combination. The intelligent rehabilitation system conducts health monitoring and evaluation according to this unified standard, which is conducive to the analysis and exchange of data. See **Figure 4**[36].

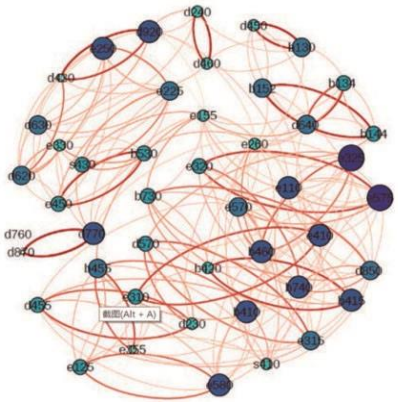

Figure 4. ICF network of chronic ischemic heart disease.

Health intervention standard system

International Classification of Health Intervention (ICHI), is a classification of health intervention from the World Health Organization Family International Classifications (WHOFICs)[37]. ICHI adopts the "goal-behaviour-means" three-axis analysis model to intervene on body function and structure, activity and participation, and environment. Each individual has a personalized ICF health network, and therefore a personalized ICHI intervention network. Provide an entrance on the client side to request medical interventions from medical institutions (e.g. body structure and function). Generate a rehabilitation management plan to provide home intervention (such as activities, participation, and home environment), and access the Home Intelligent Rehabilitation System. For intervention that require the intervention of other institutions (such as work and outdoor environment), the environmental intervention recommendations are transmitted to the relevant departments through the network and the cloud.

4. Intelligent rehabilitation practice exploration

In order to verify the feasibility of the implementation path of intelligent rehabilitation, we focus on hypertension rehabilitation to carry out a series of work, in order to form specific solutions in practice. Hypertension is the most common chronic disease in my country and the primary risk factor for stroke, myocardial infarction and even cardiovascular death[38], which seriously threatens people's health. The contents of hypertension rehabilitation include lifestyle improvement, diet control, psychological adjustment and exercise, which are very important for the intervention of hypertension. However, the awareness rate, treatment rate, and control rate of "three lows" are the general status of hypertension prevention and treatment in China[39], and the intervention of hypertension rehabilitation is not optimistic. The reasons for this are the lack of continuous blood pressure monitoring methods, the lack of early intervention concepts, and the lack of reliable hypertension rehabilitation guidance.

In response to these problems, we combined the ideas of intelligent rehabilitation, and carried out practical explorations from three aspects: The R & D of hypertension intelligent equipment, the clinical research of hypertension rehabilitation, and

the construction of hypertension rehabilitation database. In the R & D of high blood pressure intelligent equipment, non-probation continuous blood pressure monitoring equipment is the focus of the current work. Firstly, cooperate with the materials science research team to study the use of new materials such as fabric electrodes and electronic tattoos to realize the non-inductive collection of human pulse waves. Secondly, by studying artificial intelligence algorithms such as ANN, the human pulse wave signal is converted into a continuous blood pressure value. This approach avoids the traditional cuff blood pressure measurement, adopts photoelectric sensors, piezoelectric sensors and other cuff-less sensing methods, and develops blood pressure monitoring equipment into smart wristbands, smart tattoos, etc., truly realizing non-inductive continuous blood pressure monitoring. The emergence of commercialized continuous blood pressure monitoring equipment will greatly increase the awareness rate of hypertension and better help everyone manage blood pressure for life.

In the clinical research of hypertension rehabilitation, characteristic exercise and respiratory rehabilitation therapy are the main research contents. Moderate-intensity continuous training (MICT) is the traditional recommended exercise method for hypertension[40], but the process of this method is tedious, and practice also shows that its compliance is not good. As a rehabilitation method for active respiratory control, respiratory rehabilitation therapy for hypertension requires the participation of body and mind. In recent years, more and more studies have confirmed that it is effective in improving blood pressure[41,42], but its promotion rate is not high. Therefore, research on effective, interesting and distinctive exercise and respiratory rehabilitation therapy will be able to make up for the lack of current hypertension rehabilitation methods. For hypertensive exercise rehabilitation therapy, study the effect of new exercise methods such as high-intensity interval training (HIIT) and circuit resistance training (CRT) with different intervals and target intensities on blood pressure, vascular endothelial function, and inflammatory factor levels, etc. Explore to establish the optimal combined exercise program and ultimately enrich the content of exercise, thereby enhancing the fun of exercise. For respiratory rehabilitation therapy, the research combines intelligent terminal APP, electronic airflow sensor, chest and abdomen breathing motion sensor and other hardware to convert the breathing training process into a visual game. The breathing training program was applied to clinical research to explore the impact of different breathing patterns on hypertension-related health indicators, so as to guide clinical practice.

In the construction of hypertension rehabilitation database, focus on macro-functional indicators and micro-physiological and biochemical indicators closely related to the progress of hypertension. Hypertension is a systemic disease of the cardiovascular system, and its progression may affect various functions such as walking, cognition, coordination and somatosensory. Physiological and biochemical factors such as vascular endothelial function, inflammatory factor levels, blood glucose and blood lipids reflect the overall healthy environment of the cardiovascular system and are inextricably linked to the progression of hypertension. Therefore, the establishment of a hypertension rehabilitation database from these two perspectives can gradually accumulate the index data of hypertension-related populations, which can be used to explore new markers for predicting hypertension and study the intervention mechanism pathways, which is of great significance for the long-term development of hypertension prevention and treatment.

5. Future of intelligent rehabilitation

The Internet of medical things (IoMT) refers to the intelligent and convenient connection of medical staff, patients, various medical equipment and facilities through the Internet of things and communication technology. Thus, it fully supports the automatic identification, positioning, collection, tracking, management, sharing and other functions of medical data, and better completes intelligent

medical treatment and intelligent item management[43]. With the continuous development of intelligent rehabilitation, and the help of various communication and sensing technologies, "individual-equipment-medical institution" will be interconnected to form "rehabilitation Internet of things". Combined with smart hospitals[44], smart communities[45], and smart cities[46], the future "rehabilitation IoT" will cover the entire scene of individuals and provide comprehensive health monitoring and rehabilitation services. Big data and cloud computing technologies will continuously optimize and iterate algorithms to adjust evaluation and intervention strategies by storing and analyzing the massive monitoring, evaluation, intervention and prognosis data generated by the "rehabilitation Internet of things", making the system more and more accurate. Through the access of the cloud server, the government, scientific research and other related organizations will also have direct access to the health information of the whole population, which will provide a reliable basis for medical policy formulation, scientific research in the health field, revision of medical insurance standards and environmental governance, etc. See **Figure 5**.

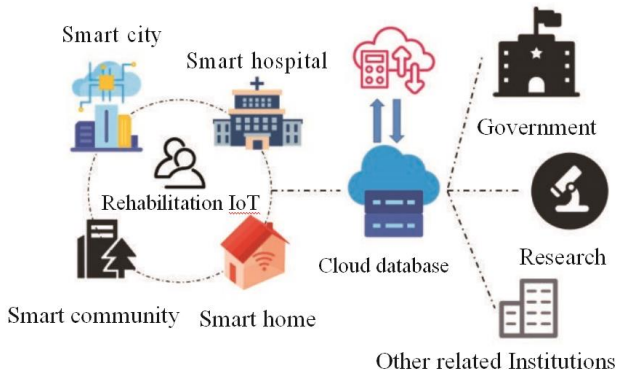

Figure 5. Future of intelligent rehabilitation.

6. Conclusions

The construction of a healthy China is an inevitable requirement for building a moderately prosperous society in an all-round way, and intelligent rehabilitation is an important means of popularizing rehabilitation services. The world is entering the digital age, and the construction and rehabilitation of a healthy China are inseparable from digital modern intelligent technologies such as wearable sensors, the Internet of things, big data cloud computing and artificial intelligence. This series of combination of intelligent technologies and rehabilitation will likely promote the development of nationalization of rehabilitation, the whole cycle of rehabilitation and the homogenization of rehabilitation. Apply WHO-FICs in the construction of intelligent rehabilitation, and endow intelligent rehabilitation with the intervention concept of "harmony between man and nature" to meet the needs of people's comprehensive health. People need, technology integration, intelligent rehabilitation is the right time!

Conflict of interest

The author declares no conflict of interest.

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