Remote Rehabilitation Model Based on BAN and Cloud Computing Technology

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Abstract—**With the improvement of living standards and the intensified social competition, the population of various chronic diseases is gradually expanded. In this study, we use a mature domestic commercial Body Area Network as our experiment platform-IVT mhealth system, a remote health care and rescue system created by IVT Corporation. This system adopts several most advanced technologies and patents in the world. It is a remote health care and rescue system, which consists of sensors, the call center and network platform. With the collaboration of medical institutions and health advisory center, it has the function of monitoring, positioning and asking for help. This system has achieved a dynamic measurement of ECG, blood pressure, blood glucose and blood oxygen. The data of users collected by wireless blood pressure meter, oximeter, ECG analyzer can be automatically sent to the cloud via cell phone and be kept as materials on records. This system provides a good platform for remote guidance, quantitative real-time monitoring and timely two-way feedback, as well as dynamic evaluation and overall adjustment for exercise rehabilitation of people on a large scale.**

Keywords-model; cloud computing; body area network; mHealth

I. INTRODUCTION

With the improvement of living standards and the intensified social competition, the population of various chronic diseases is gradually expanded, among which, the population with coronary heart disease, hypertension, diabetes and other chronic diseases is about 260 million, and the ones with sub-health status is also in a high percentage [4]. Studies show that scientific exercise can not only effectively improve the physical condition of patients with coronary heart disease, hypertension, diabetes and the groups of sub-health, but also can, to some extent, reduces the incidence and risk of illness, so as to save health care expenditure of the country and help to reduce the medical costs of patients [3]. With this thought in our mind, we focus our research on establishing the guidance model of exercise rehabilitation for patients with coronary heart disease, hypertension and diabetes.

Body Area Network and cloud platform have broad application prospects, and the combination of the two makes it possible for people on a large scale to enjoy various medical applications [10]. Body Area Network (BAN), a wireless network based on wireless sensor network (WSN), is formed by sensors collecting data of physiological parameters or biological sensors transplanted into human body [9]. It consists of a set of compact mobile sensors with communication function and a main station of the body (or BAN coordinator). Every sensor can either be worn on the body or be implanted in the body. The coordinator is not only the manager of the network, but also the gateway between BAN and external networks (such as 3GPP, WiFi, etc.), so as to enable the safe transport and exchange of data.

Cloud computing is an outcome of the evolution of the mixed concepts like virtualization, utility computing, IaaS, PaaS and Saas, as well as the latest development of distributed computing, grid computing and parallel computing [6]. Digital medical technology is a new modern technology that integrates modern computer technology and information technology into the entire health service, and indicates also the development trend and management goal of public health services [8]. Cloud computing makes it possible to solve the problems existing in the information system of the medical industry in our country, e.g., poor scalability, difficulty in maintenance, high cost of operation, difficulty in data sharing and inconvenience in using [18]. Therefore, if we can make a full use of the seamless and integrated computing and collaboration platform provided by cloud computing technology, as well as the medical hardware and software resources, it is possible to realize comprehensive sharing and collaboration of various medical information, administration management information and security information.

In this study, we use a mature domestic commercial Body Area Network as our experiment platform, that is, IVT

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mhealth system, a remote health care and rescue system created by IVT Corporation. This system adopts several most advanced technologies and patents in the world. It is a remote health care and rescue system, which consists of sensors, the call center and network platform. With the collaboration of medical institutions and health advisory center, it has the function of monitoring, positioning and asking for help. This system has achieved a dynamic measurement of ECG, blood pressure, blood glucose and blood oxygen. The data of users collected by wireless blood pressure meter, oximetry, ECG analyzer would be automatically sent to the cloud via cell phone and be kept as materials on records. This system provides a good platform for remote guidance, quantitative real-time monitoring and timely two-way feedback, as well as dynamic evaluation and overall adjustment for exercise rehabilitation of people on a large scale.

Figure 1 Remote health care and rescue system

Currently, similar studies are rare in the world that use remote real-time monitoring technology for ECG, blood pressure, blood oxygen, blood glucose (the technology of Body Area Network) and cloud computing technology so as to remotely guide the exercise rehabilitation for a large number of patients with coronary heart disease, hypertension and diabetes.

II. REMOTE GUIDANCE MODEL OF EXERCISE REHABILITATION

Remote guidance model of exercise rehabilitation is the base of scientific exercise and rehabilitation, and also the key for making proper exercise prescription [5]. In this study, we use a commercial Body Area Network as an experimental platform [7]. With the help of real-time monitoring technology of ECG, blood pressure, blood oxygen and blood glucose, we can achieve real-time quantitative monitoring and timely two-way feedback, dynamically evaluate and adjust the optimal target heart rate and best sports time of rehabilitation exercise for patients, and remotely guide exercise rehabilitation for patients with coronary heart disease, hypertension and diabetes.

A. Risk Assessment Based on Health Status

The patients are first required to do a complete medical examination, and whether rehabilitation exercise is suitable for them and which kind of exercise they shall take will be suggested based on the status and risk assessment of their health [11]. The assessment includes the general condition of the body (including gender, age, blood pressure, heart rate, respiration, blood glucose, etc.), medical history, mental condition, complications and sports-related function (muscle strength, motion range of joint, balance, walking, daily action, etc.) [13]. Then proper rehabilitation exercise plans shall be made based on the assessment results.

Generally speaking, competitive sports activities are not suitable for patients with acute diseases or those being attacked by chronic diseases [17]. The elderly over the age of 70 shall be especially careful when doing sports, and they should not take highly competitive sports. But for a majority of patients with chronic diseases (hypertension, diabetes and heart diseases), they shall participate some suitable sports activities for rehabilitation while their diseases are under control. The most suitable item of rehabilitation exercises vary from person to person [14]. For example, people with obesity shall avoid ball sports and running, and choose exercises like swimming and jogging instead; people with joint problems, heart diseases, lumbago, high blood pressure and other chronic diseases, shall not take high-intensity sports like mountaineering and swimming, and instead, may choose gentle exercise such as walking, tai chi and slow dancing.

B. Finding Optimal Target Heart Rate

The so-called target heart rate refers to the goal of heart rate that needs to be reached in sports [12]. It is an important parameter for aerobic exercise, and can be used to understand the amount and intensity of exercises. When doing sports, people need to maintain the heart rate in a reasonable range and keep it for a certain amount of time, so as to obtain the ideal effect of exercise. The reason is that heart rate that is too low leads to poor fitness effect, and heart rate that is too high would increase the risk of health problems.

The recommended target heart rates at the beginning of sports = (220– age) × (50%～75%) [19]. If the heart rate is below the lower limit of the target heart rate, it means the intensity of the exercise is too low, and that exercisers should speed up and increase the range of motion. If the heart rate is higher than the upper limit of the target heart rate, the exercise intensity may exceed the tolerance limits of the body and may even damage the body, so exercisers may slow down and reduce the range of motion.

Since the health and physical status varies from person to person, the optimal target heart rate also varies accordingly. In this regard, exercise test based on initial target heart rate is necessary. It is recommended that the values of heart rate, blood pressure, blood oxygen and blood glucose are measured after every 30 minutes of exercise, and based on the result, the

target heart rate is adjusted accordingly until the exercisers find their own most suitable target heart rates [20].

The determined target heart rate shall be used flexibly according to specific circumstances, because factors like health status, environment, seasons and mood may influence the amount of exercises. For example, when exercisers are attacked by acute diseases like cold or in extreme mood of sorrow or joy, or when the weather is rather hot, the strength and duration of the exercises shall be reduced, and so the target heart rate will be reduced accordingly to ensure safety. On the contrary, if the capability of aerobic exercises is improved, the target heart rate can be increased accordingly to guarantee the fitness effect. As for patients with coronary heart diseases who take beta blockers, the influence of drug is also taken into consideration so as to prevent tachycardia when they do exercises.

The intensity of exercise is proper with the sign of mildly speeded-up heart rate and slight sweat. If exercisers feel uncomfortable like headache, dizziness, nausea, arrhythmia, or chest tightness, dyspnea, angina, they should immediately stop the exercise. If exercisers feel pain in leg or back after doing exercise, it indicates that they have done excessive exercise and should take less next time until the discomfort disappears.

C. Making Sure The Best Time for Exercise

We may refer to the "Zi Wu Liu Zhu" rule of Chinese medicine, which is a general guidance to the best exercise time, e.g., to take exercise one and half hours after breakfast and dinner. However, as for the patient with abnormal glucose metabolism, we need to get the curve of glucose metabolism in one day so that the patient can avoid taking exercise at the lowest blood glucose level. The best exercise time is one hour before the peak of blood glucose appears. As for hypertensive patients, a curve of blood pressure is necessary so that they may avoid doing exercise at the peak of blood pressure occurs [15]. As for patients with coronary heart disease, especially those just recovered from a surgery, we need to have the curve of their heart rate, so that exercises can be avoided at the peak of heart rate. Sometimes, we may need to measure all the parameters and conduct a comprehensive assessment to determine the optimal exercise time.

D. Monitioring Target Heart Rate and Doing Exercise Accordingly

According to the optimal target heart rate, the best exercise frequency is once a day and 5～7 times a week, which should also be adjusted based on the health status of patients [16]. The result of rehabilitation is evaluated by biochemical indicators (blood pressure, ECG, blood oxygen, blood glucose and energy consumption), rate of perceived exertion (RPE) and subjective symptoms, etc.

We may also judge if the intensity of exercise is proper by considering the blood pressure, ECG, blood oxygen, blood glucose, body temperature and other indicators, as well as the PRE degree. The proposed range is $11 \leq RPE \leq 13$ (refer to TABLE III).

In addition, subjective feeling is also an important factor to the assessment result. For example, if the sense of angina is relived, and blood pressure, blood glucose return to normal, it indicates that the target heart rate and rehabilitation exercise plan is appropriate.

E. Evaluating the Result of Exercise, Adjusting the Amount of Exercise, Listening to feedback form Experts, Getting psychological Support, Returing to Further Exercise and Evaluatlion

The essence of rehabilitation is "learning, exercising, re-learning, re-exercising".

Patients should do exercise by stages according to the rehabilitation exercise plan, timely examine the effect, and constantly adjust the plan accordingly, so as to get better effect. In general, the effect would be remarkable after 6-8 weeks of exercise. It is recommended that patients receive a comprehensive evaluation every one or three weeks according to the medication, listen to the experts' feedback, get psychological support, and return to the following exercise and evaluation.

TABLE I. HEALTH STATUS and RISK ASSESSMENT TABLE

1	Gender: Male（1） Female（0）
2	Age: _____
3	Height: _____m
4	Weight: _____kg
5	Resting heart rate: _____times/min
6	Blood pressure: _____
7	Personal medical history: _____
8	Family medical history: _____
9	Medication history: _____
10	Health status of joint: _____

III. CREATING A LIBRARY OF EXERCISE PRESCRIPTION

Exercise prescription is highly personalized. Based on previous studies [2], we need to conduct an in-depth study on factors like individual vital signs, biochemical indicators, the health status of the joint and the kind of diseases, make classification and clinical test, so as to create the exercise prescription library. We classify patients into different groups according to factors including individual vital signs, biochemical indicators, the health status of the joint, the kind of disease, age, gender, treatment goal. We plan to choose 50 sample patients from each group for clinical test, track records and effect assessments, guide the rehabilitation exercises of patients with coronary heart disease, hypertension and diabetes, and set up a complete exercise prescription library.

TABLE II.EXERCISE TEST EVALUATION TABLE

Name: _____ Gender: _____ Age: _____		
Before exercise	**Test result of exercise**	**Reason for ending test**
Heart rate: ___times/min Blood pressure: _____mmHg	maximum heart rate in test: ___times/min Blood pressure: _____mmHg F.C.:_____METs（ metabolic equivalent, 1 MET＝3.5ml O_2/kg） E.C.:____METs (60%~80%) Target heart rate； _____ times/min	Heart rate reaches the maximum heart rate, and the systolic blood pressure decreases over 10mmHg.

IV. PORTING EXERCISE PRESCRIPTION LIBRARY TO CLOUD PLATFORM

After establishing the exercise prescription library, we would implement a knowledge base in the background of IVT mhealth system to support the exercise rehabilitation system for a large number of populations. We did research on the cloud computing system for exercise rehabilitation system on basis of general cloud computing infrastructure for IaaS, Paas, SaaS. The exercise prescription library is also used for researches on the technology of classification, storage, search, processing and analysis for massive information of individual rehabilitation [1]. Besides, a data center for personal exercise and health information is also created to provide remote intelligent service for rehabilitation exercise of patients with coronary heart disease, hypertension and diabetes.

TABLE III.HOW RPE DEGREE CORRELATES WITH THE EXERCISE INTENSITY

Note: maximum heart rate = 220-age

RPE degree	**Subjective feeling**	**The exercise heart rate is _____ (%) of the maximum heart rate.**
6		
7	Very very easy	<35%
8		(RPE<10)
9	Very very easy	
10		35~54%
11	Easy	(RPE10~11)
12		55~69%
13	A bit difficult	(RPE12~13)
14		
15	Difficult	70~89%
16		(RPE14~16)
17	Very difficult	
18		≥90%
19	Very very difficult	(RPE17~19)
20		100%

TABLE IV. ASSESSMENT TABLE OF THE EFFECT OF EXERCISE REHABILITATION

	Indicators	**Value**	**Remarks**
1	Heart rate/ECG		Choose the appropriate exercise in table 3 according to your RPE value. By IVT mhealth system, the heart rate value per minute and ECG would be automatically recorded.
2	Blood pressure		Measured within 1 minute after every 15 minutes of exercise with RPE degree.
3	Blood glucose		Measured within 5 minutes after 30 minutes of exercise with RPE degree.
4	Blood oxygen		Measured the last 10s of every minute
5	RPE value		Recorded every last minute of exercise
6	Self feeling		Keep feeling and watching, as make records accordingly

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REFERENCES

[1] American College of Sports Medicine. (1975). ACSM's Guidelines for Graded Exercise Testing and Exercise Prescription. Philadelphia, PA: Lea & Febiger.

[2] Wang ZZ, Guideline of ACSM exercise test and prescription. People's Medical Publishing House.（010-59780011）.ISBN 978-7-117-13194-0

[3] U.S.ARMY TELEMEDICINE PARTNERSHIP SERIES 2010."MEETING MEDICAL CHALLENGES IN A CHANGING WORLD".MHEALTH:THE USE OF CELL PHONES FOR HEALTHCARE APPLICATIONS.SATURDAY, MAY15, 2010 HENRY B.GONZALEZ CONVENTION CENTER SAN ANTONIO'TEXAS

[4] Qi XJ, Telemedicine. People's Military Medical Press. ISBN 7-80194-476-3

[5] Qi XJ, Remote ECG monitoring and diagnosis. People's Military Medical Press.ISBN 978-7-5091-2881-7

[6] Tian SY, Zhao XF, Cloud computing: realization, management and security. Beijing Mechanical Industry Press. ISBN 978-7-111-30481-4

[7] Liu HJ, A discussion on digital medicine. China Science and Technology Press.ISBN 7-5046-4356-4

[8] Wang SW, Medical computer and information technology. Beijing Tsinghua University Press. ISBN 978-7-302-17334-2

[9] Zhao GL, Network medicine. Peking Union Medicai College Press. ISBN 7-81072-060-0

[10] Gong JB, Wang R, Cui L. Study on the development of BSN and the challenge. Journal of Computer Research and Development, 2010,47(5):739-753.

[11] Wood, T.M., & Zhu, W. (Eds., 2006). Measurement Theory and Practice in Kinesiology. Champaign, IL: Human Kinetics.

[12] Chodzko-Zajko, W., Zhu, W., Bazzarre, T., Castelli, D., Graber, K., & Woods, A. (2008). "We Move Kids" – The consensus report from the roundtable to examine strategies for promoting walking in the school environment. Medicine & Science in Sports & Exercise, 40(Suppl. 7), S603-S605.

[13] King, A.C., Satarino, W., Marti, J., & Zhu, W. (2008). Multi-level modeling of walking behavior: Advances in understanding the interactions of people, place, and time. Medicine & Science in Sports & Exercise, 40(Suppl. 7), S584-S593.

[14] Zhu, W. (2008). Let's keep walking. Medicine & Science in Sports & Exercise, 40(Suppl. 7), S509-S511.

[15] Zhu, W. (2008). Promoting physical activity using technology. Research Digest, 9(3), 1-6.

[16] Fisette, J.L., Placek, J.H., Avery, M., Dyson, B., Fox, C., Franck, M., Graber, K., Rink, J., & Zhu, W. (2009). Developing quality physical education through student assessments. Strategies, 22(3), 33-34.

[17] Morrow, J.R., Jr., Zhu, W., Franks, B.D., Meredith, M.D., & Spain, C. (2009). 1958-2008: 50 Years of youth fitness tests in the United States. Research Quarterly for Exercise and Sport, 80(1), 1-11.

[18] Broglio, S.P., Zhu, W., & Park, Y. (2009). Reliability of the balance error scoring system in healthy young adults using generalizability theory analysis. Journal of Athletic Training, 44(5), 497-502.

[19] Lee, M., Zhu, W., Hedrick, B., & Fernhall, B. (2010). Determining MET values of physical activities for persons with paraplegia. Disability and Rehabilitation, 32(4), 336-343.

[20] Morrow, J.R., Jr., Martin, S.B., Welk, G., Zhu, W., & Meredith, M. (2010). Overview of the Texas Youth Fitness Project. Research Quarterly for Exercise and Sport, 81(Suppl. 3), S1-S5.