Research Status and Development Prospects of Human Vital Signs Monitoring Clothing

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Abstract: The scope of application of wearable devices is expanding, with the world population ageing. Through the monitoring and measurement of health indicators, the gradual process of diseases from physiological to pathological can be discovered in advance. Early warning of abnormal physiological phenomena can also be released by monitoring health indicators. In addition to this, appropriate methods can be found to interfere with human health trends. By monitoring the vital signs of the human body, such as ECG, heart rate, respiration rate, skin temperature, blood oxygen and skin electricity, through the integration of wearable vital signs sensors, long-term dynamic non-inductive measurement is realized, indicating the wearable human body. The vital body monitoring and acquisition system can accurately and efficiently realize the monitoring and collection and data analysis of human vital signs. This series of research results can reflect the health status of the human body more completely than the ordinary hospital clinics. Through accurate and efficient data analysis, objective and scientific evaluation can be given. Specializing in the integration and reuse of these health data is of great significance for the dynamic monitoring, disease prevention and health trend analysis of social groups.

1. Introduction
With the aging of China's population, various non-communicable chronic diseases and senile diseases have begun to show spurt growth; the high medical expenses incurred by them have placed a heavy burden on individuals and society [1]. To alleviate the medical crisis and social problems caused by this, the medical model is undergoing a profound change. From treatment to prevention is the trend of modern medicine. The "4P" medical model, namely Preventive, Predictive, Personalized, and Participatory, is being valued and promoted worldwide. The "4P" medical model emphasizes the initiative of people, emphasizes the importance of daily life behaviors on the development of diseases, and thus strengthens the intervention of individual life behaviors to achieve the goal of preventing diseases and controlling development. Prevention of disease should focus on testing the gradual process from normal physiology to pathophysiology. In this process, it is an effective way to prevent and control disease maintenance and promote individual health by measuring and monitoring health indicators, and it is possible to detect problems early and find out appropriate methods to intervene in human health trends.
The vital signs of the human body, such as ECG, heart rate, respiration rate, skin temperature, blood oxygen and skin electricity, are integrated by wearable vital signs sensors to achieve long-term continuous dynamic non-inductive measurement, and more fully reflect the human body health status [2]. For the early detection, early diagnosis and early treatment of diseases, it is of great significance that the professional treatment, integration and reuse of these health data are also positive for social group status monitoring, disease prevention and health trend analysis. It also has positive significance for the informationization and precision of personnel training in special industries such as military, civil aviation, high-speed rail and fire protection. Therefore, the development of human vital signs monitoring and acquisition system is carried out, focusing on the wearable acquisition and processing technology of long-term dynamic multi-physiological signals, and researching big data analysis methods based on deep learning and other machine learning methods. In order to achieve dynamic use of useful information such as health and physical health assessments and crisis warnings, technical support can be provided for the personalized identification and assessment of chronic disease management and special industry personnel. It is the basis for research on "energy enhancement technology" and other medical devices and drugs. The reagents establish the necessary conditions for the feedback evaluation mechanism.

2. Study Area

With the increasing demand for wearable health monitoring equipment in recent years, many research institutes and companies have successively carried out research and development of wearable health monitoring equipment, and the results of wearable health monitoring products and research are endless. For example, in Figure 2, Life Shirt is a wearable human body vitals monitoring and acquisition system developed by a US company. The system has a built-in breathing sensor to detect human respiratory signals, a built-in ECG sensor to detect human ECG signals, and a built-in gyroscope to monitor the human body's motion posture. The system can also be connected to other external devices to measure human blood pressure signals and blood oxygen saturation. However, the disposable adhesive electrode used in the life shirt is easy to cause discomfort when worn.

![Figure 1](image1.png)  
Figure 1. (A) Connected home medical monitoring devices (in millions) 2011 to 2017; (B) The world market for telehealth from 2014 divided in the main areas (CHF-congestive heart failures; COPD-chronic obstructive pulmonary disease).

![Figure 2](image2.png)
Equivital in the UK has also launched a dynamic vital sign monitoring system called Life Monitor. The system consists of a Sensor Electronic Module (SEM) and a shoulder strap. The actual object is shown in Figure 3. In addition, in recent years, the market value of wearable devices has become higher and higher, and there is a trend of blowout.

3. Latest technology and method research

3.1 Single lead ECG
At present, a low-power wearable, wireless charging and wireless transmission ECG monitoring system has been developed [3]. The single-conducting ECG module is shown in Figure 4. The system measures and records heart rate and ECG waveforms. Through the analysis of ECG data, early warning of major cardiovascular diseases can be made, and ECG data can be directly uploaded to the cloud for calculation and analysis to assist doctors in decision-making. At the same time, the respiratory rate extraction algorithm based on ECG signal is completed.

3.2 Body temperature
At present, the body temperature measurement module based on infrared temperature measurement module MLX90615 and RTD LMT70A has been developed, and the measurement is higher than 0.2°C in the body temperature range. Figure 5 shows the black body temperature measurement experiment result of the infrared temperature measurement module. At present, the TMP116 body temperature monitoring module based on CMOS temperature sensor has been successfully developed, and the measurement is higher than ±0.1°C in the body temperature range (32°C~42°C).

3.3 Transmissive non-invasive oxygen saturation
According to the difference of absorbance of red and infrared light between oxyhemoglobin and
3.4 Skin conductance
Skin conductance can be used as an indirect indicator of sympathetic activity, and can also be used as an indicator to evaluate emotional arousal levels and certain psychological activities [4]. The development of a skin electrical module has been completed, as shown in Figure 3.3. Using the DC voltage method, the two electrodes are respectively connected to two parts of the skin, and the electrodes are connected in series with the galvanometer and the external power source. When the circuit is turned on, current conduction occurs, and the galvanometer pointer is deflected. If the subject is psychologically excited, it will increase the electrical conductivity of the circuit and increase the skin conductance.

3.5 Continuous dynamic blood pressure
At present, the PTT algorithm-based blood pressure measurement watch has been successfully developed. As shown in Figure 6, the continuous dynamic blood pressure measurement technology based on pulse wave transit time (PTT) is studied, and the wearable ECG and PPG signal denoising combined with the acceleration signal are developed. The method and the long-term continuous dynamic physiological signal processing method based on deep learning, the current blood pressure measurement watch needs to be calibrated by standard sphygmomanometer before use, and the measurement accuracy after calibration can reach 5±8mmHg.

Figure 6. PTT measurement principle and algorithm verification

4. Research contents that need breakthrough at this stage
At present, the research on wearable vital signs monitoring and collection system products for special fields can be carried out in the following aspects:

4.1 Wearable vital sign data "non-inductive" acquisition technology research
To study the organic combination of electronic fabrics, microelectronics and other flexible sensing technologies to achieve "non-inductive" continuous measurement of multi-lead ECG, heart rate and respiration rate. The entire development process follows the principles of continuity, low power consumption, safety and reliability.

4.2 Construction of vital signs basic data platform
All measured parameters are uploaded by Bluetooth wirelessly, and connected to the local server through Bluetooth relay. Large-time data collection and accumulation through long-term, multi-point and different environmental conditions, and temperature, humidity, pressure and other environments can be realized through software management. The parameters are entered and analyzed, and the basic data platform of military training personnel is constructed. Through the application software setting, medical basic data such as ECG, heart rate, respiratory rate, body temperature, skin electricity and
blood oxygen are processed, stored, displayed and analyzed.

4.3 Residual physical energy and mind and body state evaluation algorithm based on machine learning

The machine learning technology is used to analyze and process the vital signs information of the test participants [5]. By collecting the parameters of the human body's multiple vital signs and adopting the combination of algorithm threshold and machine learning, the time domain features (such as ECG R wave amplitude) can be counted. Learning characteristics (such as mean respiratory rate and standard deviation of respiratory rate), as the input of neural network or SVR, establish a human health state identification model, quantitatively assess the physical and mental condition of the participants, and issue an alert when individual data or assessment results are abnormal.

4.4 Environmental Adaptability Study of Wearable Multi-Physical Products

The system is easy to operate, easy to use and comfortable to wear. The circuit module is detachable, the fabric clothes can be washed, easy to maintain, and have good service adaptability [6]. It can be used normally in a variety of harsh border environments such as plateau, desert, severe cold, and damp heat. The waterproof and dustproof level is designed to meet the requirements of the product, and it will not affect the normal use of the product when it is exposed to rain or strong water spray.

5. Conclusion

The human vital signs monitoring and collecting system can realize long-term continuous dynamic non-inductive measurement based on the normal actions of the participants, and it can reflect the health status of the human body more completely than the previous outpatient health information. Find and clarify its laws, characteristics and influencing factors, and give objective scientific analysis and evaluation, professionally process, integrate and reuse these health data, and also have status monitoring, disease prevention and health trend analysis for social groups. The positive significance of this product is to provide technical support for the whole process of data monitoring in the actual military training process of the military. The product can quantitatively assess the physical and mental condition of participants and enable scientific analysis of human-computer adaptability. The product also effectively evaluates the ability of people and robots to coordinate. The various systems of the product help to enhance the data. The authenticity of the collection and the interaction between the field environment and the combat troops can fully verify and evaluate the actual military training program plan and achieve the goal of improving the level of actual combat military training in China. In the civil aviation, high-speed rail and fire-fighting special training, the informationization of personnel training has positive significance.

Wearable devices are in a multidisciplinary, knowledge-intensive, capital-intensive, high-tech industry with fast technology updates, advanced production methods, strong dependence on professionals, high profits and high thresholds. The high-end market is monopolized by foreign manufacturers. The high cost of purchase is not conducive to the widespread promotion of hospitals, communities and families. The smooth advancement of this product will help local companies to achieve greater technological breakthroughs in the field of wearable health status identification and physical assessment. This product breaks through the technical barriers of foreign manufacturers and forms a core technology reserve, which greatly reduces the procurement cost. The product monitoring system can reduce the national and hospital and even individual medical expenditures to optimize the existing monitoring ecology, improve the existing medical quality of the Chinese people, and have significant social and economic benefits.

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