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REVIEW

Application of Wearable Devices in Psychological Rehabilitation Nursing

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Abstract

This paper introduces the definition, classification and basic structure of wearable devices, and describes in detail the current state of their application in monitoring and assessing physical and mental health status, in intervening in illness and promoting psychological rehabilitation, and in predicting mental health risk. It analyses the problems that arise in the use of wearable devices and puts forward corresponding countermeasures, considers the direction in which wearable devices are likely to develop in the field of psychological rehabilitation, and observes that, as wearable devices advance, their application in psychological rehabilitation nursing will become ever more extensive.

Keywords: wearable device; psychological rehabilitation; mental illness; mental health; rehabilitation nursing

Introduction

As the pace of social life has quickened and the pressures of work and daily living have accumulated, psychological problems have come to affect the physical and mental health of the Chinese population at large, while effective psychological rehabilitation nursing is able to improve patients' mental health[1]. Most people, however, overlook psychological problems and lack any effective means of monitoring them, and their condition therefore progresses to severe psychological and psychiatric illness that does serious harm to daily life. Conventional assessment of mental health relies on questionnaires, interviews and similar methods, and so cannot avoid being influenced by subjective factors.

How to build a psychological rehabilitation system and deliver psychological rehabilitation nursing to both inpatients and the general population has therefore become a key problem to be solved. With advances in the internet and in big data processing, wearable devices combined with software processing systems have gradually been applied to the guidance of psychological rehabilitation nursing[2]. Because they are convenient to wear, wearable devices can transmit psychological monitoring data and provide timely and effective guidance, and they have accordingly become a promising means of delivering high-quality nursing in psychological rehabilitation. On 1 May 2022 we searched the CNKI and PubMed databases for literature on wearable devices published between 2011 and 2022, using the Boolean strings "wearable device AND (psychology OR rehabilitation OR psychological rehabilitation OR rehabilitation nursing)" for the Chinese-language search and "(wearable devices) AND (mental OR rehabilitation OR mental rehabilitation OR rehabilitation nursing care)" for the English-language search, both as topic-term searches. A total of 244 articles on the application of wearable devices in psychological rehabilitation nursing were retrieved, of which 114 were in Chinese and 130 in English; after duplicate records and studies of low relevance had been excluded by manual reading, 29 articles were finally included for summarisation. This paper summarises the current state of the application of wearable devices in psychological rehabilitation nursing in China and abroad, analyses the associated problems and proposes corresponding countermeasures.

1 Definition, classification and basic structure of wearable devices

1.1 Definition and classification

Wearable devices are portable electronic devices that are worn or carried on the body and connected to peripheral sensing equipment so that human physiological parameters can be collected. By mode of wear they fall into four classes —

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wrist-worn, head-mounted, carry-on and body-worn — as set out in Table 1. A wearable device usually works together with its corresponding software application to acquire human data for analysis[3].

Table 1 Summary of the types and characteristics of wearable devices

Type	Representative products	Functional characteristics	Drawbacks
Wrist-worn	Apple Watch, Xiaomi Smart Band, Huawei Watch, Fitbit trackers and similar	Measures heart rate, blood oxygen saturation, blood pressure, sleep duration, step count and other physiological data. It is easy to carry, and has an operable display screen with rich interactive functions as well as a reminder function	Must be connected to a phone and used with the corresponding app; measurement error; battery life is relatively short and frequent recharging is required
Head-mounted	Google Glass, VR headsets, medical brainwave instruments, Bluetooth earphones from various brands and similar	Presents visualised or audible information directly to the user, and can measure information such as brainwaves and body temperature	Few interactive functions and complex operation; unfriendly to users with visual or hearing impairment
Carry-on	Huawei Tag, Apple AirTag and similar	Has an anti-loss reminder function; good water and dust resistance and good portability; exceptionally long battery life	Extremely limited function with no interaction; does not contact the body and cannot measure physiological data
Body-worn	Smart T-shirts, running shoes and socks from Nike, Adidas and Xiaomi, and medical body-worn equipment and similar	Has specific professional functions, such as detecting heart rate, sleep apnoea, body temperature and physical activity, with relatively high measurement accuracy	Small or absent display; demanding requirements for material comfort and thinness; battery life somewhat poor

1.2 Basic structure

A wearable device involves the links of data acquisition, transmission and processing, and its wearing system consists mainly of three basic units: (1) the sensing unit, which acquires physiological data and activity signals; (2) the communication unit, which chiefly establishes the connection between the wearable device and its software and hardware and is used to receive data in the background; and (3) the processing unit, which collates, classifies and processes the raw physiological data received[4]. The basic units of the wearing system are shown in Figure 1.

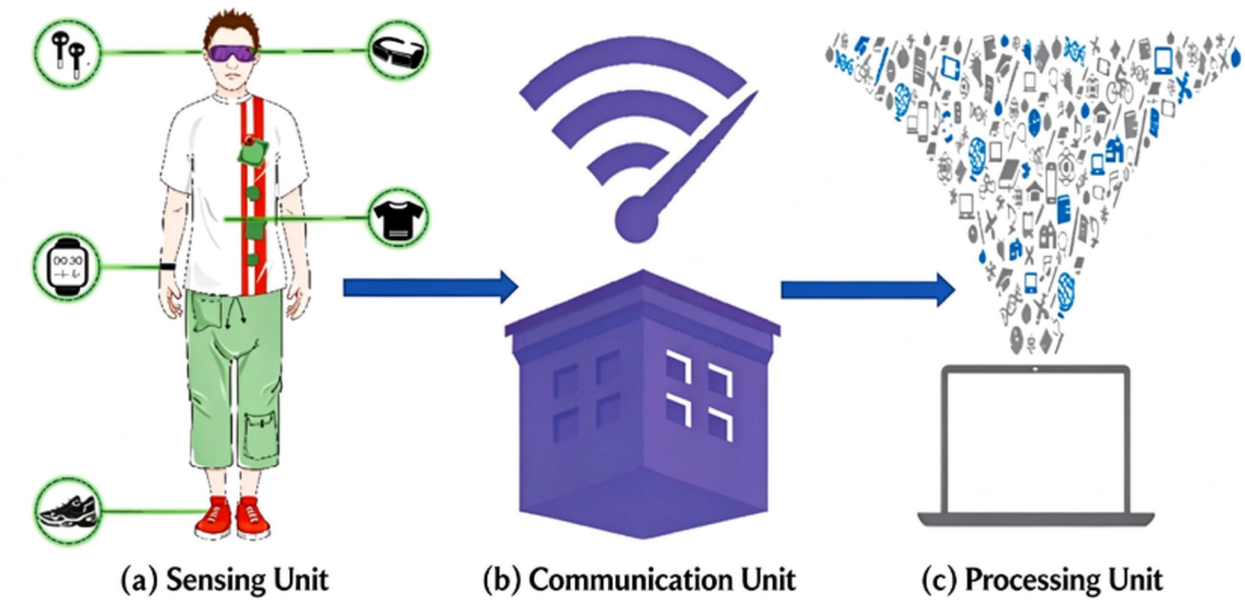


Figure 1 Basic units of the wearing system

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2 Characteristics and advantages of wearable devices in psychological rehabilitation nursing

2.1 Portability and mobility

Because wearable devices are small and easy to move, patients accept them readily. They can be carried outside the hospital so that psychological rehabilitation nursing guidance is available at any time and in any place, which is conducive to continuing nursing in psychological rehabilitation and promotes the regional development of psychological rehabilitation networks.

2.2 Intelligent assessment

Conventional mental health assessment generally uses questionnaires, interviews or third-party rating, and is accordingly liable to subjectivity and inaccurate assessment. Wearable devices, combined with their supporting software, can acquire physiological signals and patients' emotional characteristics, which avoids the shortcomings of conventional assessment and is more conducive to targeted psychological rehabilitation nursing intervention.

2.3 Real-time warning and feedback intervention

Wearable devices can give a real-time warning of adverse emotions and physiological signals that may arise, can deliver psychological rehabilitation nursing advice through the corresponding mobile app, and can feed the warning back to the relevant psychological rehabilitation nursing staff, who can then implement targeted interventions and so prevent the psychological problem from worsening further.

2.4 Follow-up supervision

Follow-up supervision at present consists mostly of nursing staff telephoning patients in one direction only, which patients accept poorly, disturbs others and yields poor follow-up. When a wearable device issues a warning, however, two-way follow-up supervision can be carried out on the accompanying software or mobile app in response to that signal, which patients accept more readily and in which they feel more involved.

3 Current state of application of wearable devices in psychological rehabilitation nursing

Wearable devices are at present used widely in rehabilitation fields such as neurological rehabilitation, postoperative orthopaedic rehabilitation and telemedicine rehabilitation[5], and have begun to be applied in psychological rehabilitation, where they play a positive part in promoting mental health[6]. A wearable device chiefly acquires physiological data through peripheral sensors, after which the data are analysed by software and assessed by professional nursing staff, who then give guidance. In this way the method can monitor physical and mental health, predict mental health risk and intervene in the progression of mental illness, and so promote the patient's psychological rehabilitation.

3.1 Application in psychological rehabilitation nursing in China

3.1.1 Monitoring and assessing physical and mental health status

Portable wearable devices such as wrist-worn watches, fitness trackers and head-mounted VR headsets can effectively monitor changes in mental health in different populations at a distance, and so allow classified intervention according to mental health status. Zhao Xiangdong et al.[7] used Jiule watches to monitor and compare data from people infected with coronavirus disease 2019 before and after isolation along the dimensions of activity level, sleep quality and health parameters, and found that wearing a Jiule watch relieved the fear and anxiety brought on by a sudden epidemic event and helped patients to develop sound living habits. Yang Sihao[2] had participants wear multi-sensor wristbands to collect a range of psychological features, explored the differences in psychological features between positive and negative emotion, and thereby built a model relating sensing features to physical and mental health status, which is conducive to real-time monitoring of negative psychological features and to intervention. Zhao Zhan et al.[8] used wearable sensing devices to acquire individual physiological signals in real time and assessed psychological stress in the individual continuously over the long term; combined with a random forest algorithm, the approach classified, identified, monitored and assessed stress states more accurately. Jin Jikun[9] designed a multi-sensor wearable watch for data acquisition and proposed an attention-mechanism-based feature fusion module capable of classifying a variety of mental health states. In summary, wearable devices can not only monitor at a distance but also classify according to different psychological states, and so achieve effective treatment matched to the condition.

3.1.2 Promoting high-quality psychological rehabilitation nursing

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Early high-quality psychological rehabilitation nursing works together to promote the patient's recovery from illness, and collecting early psychological and physiological state data with wearable devices and intervening on that basis can raise patients' sense of wellbeing and satisfaction with care, and so promote a virtuous circle in the patient–nurse relationship. Dong Kun[10] used a smart wearable device (the NEO-SMART activity monitor) to monitor the out-of-hospital rehabilitation exercise of patients after anterior cruciate ligament reconstruction, and found that patients' need for psychological guidance and for rehabilitation exercise was at a high level while their corresponding knowledge was deficient; smart connected wearable devices can overcome these shortcomings and produce positive rehabilitation nursing adherence, raise the satisfaction of patients undergoing out-of-hospital rehabilitation, and promote the extension of early high-quality psychological rehabilitation nursing. Ma Xuna[11] found that the main reasons for poor sleep quality in inpatients include the effects of light and noise, nurses' night rounds and psychological stress. To address these problems she designed a wearable smart sleep mask with integrated eye and ear cover that reduces the effects of light and noise and can feed important vital signs back to nurses, helping to improve sleep and relieve psychological stress. At the same time the device can lighten the workload of night-shift nurses and deliver high-quality psychological rehabilitation nursing. In summary, wearable devices can meet the home-based psychological rehabilitation needs of patients outside hospital and guarantee the psychological needs of patients inside it, effectively raising the quality of nursing service and building a bridge of communication between patients and clinical staff.

3.1.3 Promoting psychological recovery from illness and after surgery

Patients who fall ill or undergo surgery often face both a physical and a psychological obstacle. Previous means of psychological rehabilitation nursing, such as conversation and enquiry, cannot always intervene in a timely or targeted way, whereas wearable devices combined with software data processing can often detect signals of psychological disturbance in time, which is conducive to psychological rehabilitation nursing during illness and after surgery. Addressing the problems that stroke rehabilitation equipment is expensive, and that the movements it requires are monotonous and tedious, Xian Pengquan et al.[12] designed a wearable upper limb rehabilitation device on the basis of psychotherapy, in which playful games both encourage patients to take an active part in rehabilitation training and benefit psychological recovery and recovery from stroke. Chen Shujuan et al.[13], reviewing the application of mobile health technology in the field of addiction, found that wearable devices have functions of education, assessment and monitoring, self-management of the disease course and psychosocial intervention, and that patients in underdeveloped remote areas or with chronic conditions requiring long-term intervention can in particular use wearable devices for psychological rehabilitation intervention at any time and in any place. Jiang Yifan[14] designed a set of maternal and infant wearable devices together with a host unit and a supporting mobile phone application that monitors the physical and psychological-emotional state of mother and infant in real time and feeds it back promptly to the family and to nursing staff, which can prevent and relieve the psychological disorders that arise from emotional instability in postpartum women and help them through the postpartum recovery period smoothly. While a patient is in hospital and after recovery from illness, the attention of clinical staff and family is mostly concentrated on treating the illness and on rehabilitation, and the patient's psychological state is easily overlooked; wearable devices, however, can attend to changes in the patient's mental health in good time, so that physical and psychological recovery proceed together.

3.2 Application in psychological rehabilitation nursing abroad

As in China, work abroad on wearable devices has concentrated on their applicability and acceptability in psychological rehabilitation nursing and on psychological intervention trials; unlike China, however, there are more trials of wearable devices in psychological rehabilitation abroad, which have broken through the constraints of conventional rehabilitation nursing and raised patients' satisfaction with rehabilitation nursing.

3.2.1 Monitoring and assessing physical and mental health status

Although psychological rehabilitation physicians can make a professional assessment of a patient's psychological state, they lack timely and effective mental health monitoring, and their grasp of the patient's mental health information is often delayed; wearable devices, by contrast, can monitor psychological and physical health continuously. Wu et al.[15] built a psychological stress index model on the basis of psychological, biochemical and physiological data and applied it to a wearable electronic vest to monitor the wearer's daily stress continuously, so that psychological state can be regulated before severe mental illness develops and the individual is offered personalised stress management suited to their needs in a dynamic everyday environment. Yang et al.[16] reviewed the benefits of electronic wearable textiles for healthy ageing and found that they can be used to monitor psychological and physical health and have the function of maintaining mental health and promoting activity; such wearable textiles are therefore suitable for long-term monitoring and for carrying health management systems. Nelson et al.[17] pointed out that although wearable devices cannot replace the medical electrocardi-

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ograph in measuring heart rate, they can serve as a supplement to medical equipment and help researchers to collect data continuously, so that psychological stress and cardiovascular disease can be studied better. Al-Saggaf et al.[18] compared the running time of deep learning and machine learning algorithms and found that deep learning applied to wearable devices has the advantage of real-time monitoring: it can assess stress in real time from raw electroencephalogram data with high accuracy and can feed information back promptly. Real-time mental health monitoring makes it easier to adjust psychological rehabilitation methods in good time, can shorten the patient's psychological rehabilitation cycle, and will advance the dynamic monitoring of psychological rehabilitation to a considerable degree.

3.2.2 Predicting mental health risk

The real-time monitoring of psychological state made possible by wearable devices also makes it possible to predict mental health risk, and early prediction of that risk is particularly important in environments and occupations where psychological stress is likely to arise. Terry et al.[19] used a mobile health application installed on a wearable device or a mobile phone to help users recognise a psychological state or illness and to connect patients with an online therapist, so that mental health problems can be predicted and diagnosed dynamically and patients with such problems can carry out self-assessment and early prediction of them. Moshe et al.[20] found that data collected with wearable devices, together with a smartphone, can predict and identify individuals who have or may have a mental health risk, and can in particular monitor and analyse sleep-related data, so that preventive measures can be implemented as early as possible and the limitations of conventional mental health screening overcome. Dalmeida et al.[21] built a model predicting psychological stress level from heart rate variability as a feature; the model is applicable to non-invasive wearable devices and can be used to monitor and relieve psychological stress. Predicting psychological risk allows targeted relief of and treatment for psychological stress at an early stage, and prevents the psychological problem from worsening further.

3.2.3 Intervening in mental illness and promoting psychological rehabilitation

For people in the general population or inpatients who have already developed a mental illness, timely and effective psychological intervention is especially important: by monitoring and analysing the user's data, wearable devices can deliver psychological rehabilitation guidance through encouragement and suggestion, improved self-management and the promotion of social contact, among other means. Hodges et al.[22] developed a wearable digital camera that records what the wearer does during the day and can stimulate and restore memory, which may benefit patients with psychological problems. Cattivelli et al.[23] used wearable devices to monitor and give feedback on the lifestyle of patients with obesity while collecting mental health data, so as to cultivate a beneficial lifestyle, promote mental health and improve quality of life. Yen[24] showed in a randomised controlled trial that, from a psychological point of view, smart wearable devices are conducive to shaping a healthy lifestyle and improving quality of life. Yunusova et al.[25] demonstrated in a prospective pilot study that the use of individualised wearable devices is beneficial for psychological rehabilitation. Signorelli et al.[26] reported that mobile wearable devices can provide psychosocial intervention for patients with cancer who have psychological problems, improving those patients' coping skills in relation to their illness and so promoting their mental health and recovery. Nguyen et al.[27] found that a wearable real-time anxiety detection device can raise awareness of anxiety symptoms in children with autism spectrum disorder and has a positive effect on physical and mental health. Choudhury et al.[28] tested a database model and found that wearable devices can capture real-time psychosocial, physiological and behavioural change data, have a clear negative regulatory effect on psychological stress, strengthen self-care and self-management, and provide clinical staff with individualised real-time data on which to base better-informed nursing decisions. Gallos et al.[29] used wearable devices as a vehicle, through a mobile health application, to record the psychological, emotional and physical state of citizens and patients and to encourage them to take part in social and self-care activities, promoting the development of mental health. The application of wearable devices in psychological rehabilitation nursing can effectively give early warning of mental health problems and intervene in psychological problems, and so lighten the workload of nursing staff and improve patients' adherence, allowing recovery from illnesses in which psychological problems readily arise — cancer and physical disability, for example — to be promoted together with the patient's psychological rehabilitation, and shaping a sound and healthy approach to psychological rehabilitation.

The literature on the application of wearable devices in psychological rehabilitation nursing is summarised in Table 2.

Table 2 Summary of the literature on the application of wearable devices in psychological rehabilitation

Author	Year	Type of wearable device	Findings and significance
Hodges et al.[22]	2011	Carry-on	May benefit patients with psychological problems
Zhao Zhan et al.[8]	2017	Body-worn	Better classification, identification, monitoring and assessment of stress states

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Author	Year	Type of wearable device	Findings and significance
Ma Xuna[11]	2018	Head-mounted	Promotes sleep, relieves psychological stress and at the same time raises the quality of psychological rehabilitation nursing
Terry et al.[19]	2018	Carry-on	Dynamically predicts and diagnoses psychological problems, helping patients with such problems towards earlier recovery
Cattivelli et al.[23]	2018	Wrist-worn	Promotes mental health and improves quality of life
Wu et al.[15]	2019	Body-worn	Continuously monitors the wearer's daily stress and provides personalised stress management
Yang et al.[16]	2019	Body-worn	Monitors psychological and physical health; suitable for long-term monitoring and for supporting health management systems
Signorelli et al.[26]	2019	Various types	Improves patients' coping capacity in relation to cancer and promotes mental health and recovery from illness
Yang Sihao[2]	2020	Wrist-worn	Real-time monitoring of and intervention in negative psychological features
Jin Jikun[9]	2020	Wrist-worn	Classifies a variety of mental health states
Xian Pengquan et al.[12]	2020	Body-worn	Encourages patients to take an active part in rehabilitation training while promoting psychological recovery, and is of greater benefit for recovery from stroke
Chen Shujuan et al.[13]	2020	Wrist-worn, carry-on	Patients in underdeveloped remote areas or needing long-term intervention can receive psychological rehabilitation support at any time and in any place
Jiang Yifan[14]	2020	Carry-on	Can prevent and relieve emotional instability in postpartum women and help them through the postpartum recovery period smoothly
Nelson et al.[17]	2020	Wrist-worn	Wearable devices can supplement medical equipment and collect data, allowing better study of psychological stress and cardiovascular disease
Zhao Xiangdong et al.[7]	2021	Wrist-worn	Monitors data from people infected with coronavirus disease 2019 before and after isolation, relieving fear and anxiety
Dong Kun[10]	2021	Body-worn	Improves the satisfaction of patients undergoing out-of-hospital rehabilitation and advances the extension of early high-quality psychological rehabilitation nursing
Al-Saggaf et al.[18]	2021	Head-mounted	Deep learning applied to wearable devices has the advantage of real-time monitoring and can assess stress in real time from electroencephalogram data
Moshe et al.[20]	2021	Carry-on	Provides a valuable data source for individuals who have or may have a mental health risk
Dalmeida et al.[21]	2021	Wrist-worn	Predicts psychological stress characterised by heart rate variability
Yen[24]	2021	Wrist-worn	Conducive to shaping a healthy lifestyle and improving quality of life
Yunusova et al.[25]	2021	Carry-on	The use of individualised wearable devices is beneficial for psychological rehabilitation
Nguyen et al.[27]	2021	Body-worn	Has a positive effect on the physical and mental health of children with autism spectrum disorder
Choudhury et al.[28]	2021	Various types	Has a clear negative regulatory effect on psychological stress and strengthens self-care and self-management
Gallos et al.[29]	2022	Various types	Encourages citizens to take part in social and self-care activities and promotes mental health

4 Problems with wearable devices and countermeasures

4.1 Data

4.1.1 Insufficient accuracy of data monitoring

Although wearable devices can monitor psychological state through physiological indicators such as heart rate variability, sleep and respiration, their heart rate monitoring is inaccurate and there is error in the measurement of sleep duration. Chip technology can be upgraded and new monitoring models established so that patients' mental health data are monitored in real time from several directions and angles.

4.1.2 Inconsistent metrics for data measurement

At present there is no unified metric for the standard that must be met, in the assessment of mental health risk by wearable devices, before psychological intervention guidance is required, and this makes it difficult to determine when and in what form to intervene. Establishing a unified metric of mental health risk is therefore of the utmost importance, and in particular a national mental health database should be established so as to unify the metrics of mental health data.

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4.1.3 Inadequate protection of data privacy

Some mainstream wearable devices are at present used in conjunction with a mobile app, but the user's data are not protected, and there is a risk that private user data may be disclosed without the user's knowledge. Legislation on the privacy of wearable device data should therefore be established and implemented, so that users' private information is never disclosed at will and users' data security is safeguarded. Moreover, most devices depend excessively on a mobile phone or computer to process information and cannot perform their functions independently.

4.2 Other aspects

Wearable devices are at present still relatively expensive for the general public, and they also suffer from short battery life and poor comfort, which hinder their application in the field of mental health nursing[30]. As core technologies such as chip technology and graphene supercapacitor batteries develop, however, and as various wearable materials improve, the price, battery life and comfort of wearable devices will become acceptable to users, and wearable devices will accordingly become widespread in the field of mental health nursing.

5 Conclusion

A range of wearable devices has now been applied to mental health monitoring, psychological rehabilitation nursing and the early detection of mental illness, where they have provided considerable effective help and helped to raise people's quality of life. At the same time, the following challenges remain: the accuracy of the data collected is not high, the metrics are not unified, and there is a risk of disclosure of users' information and privacy.

With the continuing development of biomaterials and the demands of psychological rehabilitation nursing, the development of wearable devices in the field of psychological rehabilitation is likely to proceed as follows: (1) miniaturisation and long battery life will be the directions given priority and most urgently in need of solution; (2) wearable devices will gradually cease to depend on smartphones and will independently perform the functions of acquiring psychological information and processing data; (3) with the rapid development of 5G and big data technology, wearable devices will achieve more precise monitoring of psychological state and personalised psychological intervention; and (4) given the rapid progress of biomaterials research, customised embedded electronic devices able to remain in the body for long periods will become the ultimate form of the wearable device, providing more sustained and effective support for psychological rehabilitation nursing. As wearable devices develop, their application in psychological rehabilitation nursing will become ever more extensive.

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