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Mini Review

Research Progress on Wearable Textiles for Cardiovascular Monitoring

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Abstract

Cardiovascular disease (CVD) is a leading cause of death and disability worldwide, making continuous cardiovascular monitoring essential for early detection, risk assessment, and long-term management. Traditional 12-lead electrocardiograms (ECGs) and Holter monitoring provide important diagnostic information but are limited by short monitoring duration, poor wearability, and limited suitability for long-term home use. With advances in flexible electronics, smart textiles, biosensors, and wireless communication, textile-based wearable systems have emerged as a promising approach for cardiovascular monitoring. By integrating flexible sensors into garments, these systems can continuously acquire ECG, photoplethysmography (PPG), and other physiological signals for real-time assessment. This review summarizes recent advances in key technologies, clinical applications, current challenges, and future directions of smart textiles for cardiovascular monitoring, aiming to support their further development in cardiovascular disease management and personalized healthcare.

Keywords: Wearable textiles; Smart textiles; Cardiovascular monitoring; Flexible electronics

Introduction

Cardiovascular disease is a major global health burden, and conditions such as arrhythmias, hypertension, coronary heart disease, and heart failure require continuous monitoring for timely detection and treatment [1-2]. Conventional 12-lead ECG provides only short-term information, while Holter monitoring is limited by bulky equipment, multiple leads, and poor long-term wearability [3,4]. Consumer wearables such as smartwatches have improved continuous monitoring, but wrist-based single-lead ECG and PPG remain susceptible to motion artifacts and site-related limitations [2,4-5].

Smart textiles provide a promising alternative for long-term cardiovascular monitoring [6,7]. By integrating conductive fibers, flexible electrodes, and microelectronics into clothing, they enable continuous, non-invasive physiological monitoring while maintaining comfort [7-10]. Combined with wireless communication and artificial intelligence, these systems also support remote data analysis and disease management [2,11]. Current research is therefore shifting from basic sensing performance toward signal quality, durability, user experience, and clinical translation.

Current Status of Wearable Textile Cardiovascular Monitoring

Wearable textiles combine smart textile technology with flexible electronics to enable real-time acquisition and transmission of physiological signals [6,7,12,13]. Their softness, breathability, and wearability make them suitable for long-term monitoring in daily life [8].

Current designs include smart T-shirts, chest straps, compression garments, and rehabilitation clothing [10,14]. ECG remains the principal monitoring target, while PPG, respiratory, temperature, and motion sensors are increasingly integrated for multiparameter monitoring. At rest, dry textile electrodes can generally record recognizable P waves, QRS complexes, and T waves with good agreement with conventional electrodes[15, 16]. Under dynamic conditions, optimized garment structure and electrode placement can help reduce motion artifacts [14,17].

With advances in telemedicine, wearable textiles are also evolving from simple sensing devices into platforms for remote monitoring, abnormal-event alerts, and chronic disease management.

Applications of Wearable Textiles in Cardiovascular Diseases

Arrhythmia Screening

Paroxysmal atrial fibrillation is one of the most promising applications of wearable textiles[3, 18]. Because intermittent arrhythmias may be missed by short-term ECG or 24-hour Holter monitoring, prolonged textile ECG monitoring can improve the likelihood of detection. Combined with artificial intelligence, these systems can automatically identify atrial fibrillation, premature beats, and bradycardia and transmit suspected abnormalities for remote clinical review [11,18].

Management of Chronic Cardiovascular Diseases

Wearable textiles also show potential in hypertension, coronary heart disease, and heart failure. Combined ECG and PPG monitoring may support continuous cuffless blood pressure estimation and trend assessment. In heart failure, simultaneous monitoring of heart rate, respiratory rate, activity, and posture may help identify changes in clinical status [5,19].

During cardiac rehabilitation, smart garments can monitor heart rate and exercise intensity in real time, providing objective information for personalized exercise planning and improving training safety [2,14].

Telemedicine and Health Management

Wearable textiles can transmit physiological data through Bluetooth, Wi-Fi, or mobile networks to cloud-based platforms, supporting remote monitoring, abnormal-event alerts, and long-term health records [9-10]. This model is particularly useful for older adults and patients with chronic cardiovascular disease by extending monitoring from hospitals to homes and communities. Integration with the Internet of Medical Things and electronic health records may further strengthen their role in digital healthcare [2,20].

Issues and Challenges

Several challenges still limit the clinical adoption of wearable textiles. First, movement can cause relative displacement between the fabric and skin, producing motion artifacts that reduce ECG and PPG signal quality [15,17]. Second, repeated stretching, friction, and washing may degrade conductive materials, making durability and washability important technical issues.

Clinical evidence also remains limited because many studies involve small samples or laboratory settings. Large multicenter trials are needed to evaluate long-term effectiveness and clinical utility [6,21]. In addition, the collection and wireless transmission of health data raise concerns regarding privacy, cybersecurity, interoperability, and device regulation.

Outlook

Future wearable textiles are expected to become more integrated, intelligent, and precise. Advances in flexible conductive materials, self-powered systems, and high-performance sensors may improve durability, comfort, and long-term stability [12,20]. At the same time, multimodal sensing, artificial intelligence, and big-data analysis may shift these devices from passive monitoring toward risk prediction and personalized management.

Further integration with telemedicine, IoMT, and electronic health systems could enable continuous cardiovascular care across hospitals, homes, and communities. Standardized validation, stronger clinical evidence, and improved data-security frameworks will be essential for widespread clinical adoption [9,22].

Conclusion

Wearable textiles integrate smart fabrics, flexible electronics, biosensors, and artificial intelligence to enable continuous and non-invasive cardiovascular monitoring. They have shown considerable potential in arrhythmia screening, chronic disease management, cardiac rehabilitation, and telemedicine [3,18]. However, motion artifacts, durability, limited clinical validation, and data-security concerns remain important barriers. Future interdisciplinary research should focus on improving reliability, standardization, and clinical applicability to support the broader use of wearable textiles in cardiovascular healthcare.

Author contributions

H. Chen, designed and supervised the study. Z. Qi performed data analysis and drafted the manuscript.

Disclosures

None.

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