

Real-Time Identification of the Pre-Disease Stage Using Wearable Electronic Devices

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웨어러블 전자디바이스를 이용한 질병전단계 실시간 분석 기술에 관한 연구

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Abstract

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I. Introduction

The pre-disease stage, which is an early, reversible phase preceding overt disease, has transformative potential for diagnosing and treating chronic illnesses like depression. Drawing parallels to materials science, where increased fluctuations precede critical points in stress-strain curves, the human body exhibits amplified temporal biomarker variability during this stage. These fluctuations signal a loss of resilience, acting as early warnings of disease onset. By conceptualizing a "physiological stress-strain curve," we propose that real-time monitoring of biomarkers could enable timely interventions to restore health before irreversible damage occurs.

II. Method

To test this hypothesis, we used a mouse model of depression and continuously monitored both biomarker fluctuations and behavioral changes to identify the transition from the pre-disease stage to the disease stage. We developed a skin-attachable, wireless vagus nerve stimulation (VNS) patch, which features a 3D-printed liquid metal probe and NFC-enabled wireless power transfer, and applied this device at two different time points: during the pre-disease stage (day 7 after corticosterone injection) and during the disease stage (day 18 after injection). We evaluated the effects of VNS intervention using behavioral tests, including the forced-swim test and open-field test, and analyzed biomarker dynamics

such as changes in brain activity and blood markers to validate the critical transition points.

III. Conclusion

Our results showed that intervention with VNS during the pre-disease stage led to rapid recovery from depressive symptoms, while treatment during the disease stage was ineffective, highlighting the importance of early detection and intervention. These findings support the idea that increased biomarker fluctuations can serve as early warning signals of disease, and although further clinical validation across various diseases is needed, this approach presents a new paradigm for early detection and preventive intervention. Ultimately, real-time identification of the pre-disease stage combined with timely, non-invasive treatment could greatly improve disease prevention and health management.