УДК 616-71

ROLE OF DIGITAL BIOMARKERS IN NEURODEGENERATIVE DISEASES

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Аннотация. The advent of digital biomarkers has revolutionized the diagnostic and management landscape of neurodegenerative diseases, offering unprecedented insights into the physiological and behavioral changes associated with Multiple Sclerosis (MS), Alzheimer's Disease (AD), and Parkinson's Disease. Digital biomarkers, defined as objective and quantifiable data obtained from digital devices, include crucial metrics such as gait speed and movement analysis. In this research how digital biomarkers can reveal vital information regarding disease progression is demonstrated, and the integration of technology into clinical practice as a means to enhance patient care is highlighted. By examining the role of digital biomarkers in the context of neurodegenerative diseases, the potential for improving diagnostic accuracy and treatment outcomes is underscored in this work, ultimately leading to a better quality of life for affected individuals.

Ключевые слова: digital biomarkers, neurodegenerative diseases, Multiple Sclerosis (MS), Alzheimer's Disease (AD), Parkinson's Disease, gait speed and movement analysis

РОЛЬ ЦИФРОВЫХ БИОМАРКЕРОВ В НЕЙРОДЕГЕНЕРАТИВНЫХ ЗАБОЛЕВАНИЯХ

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Abstract. Появление цифровых биомаркеров революционизировало диагностику и управление нейродегенеративными заболеваниями, предоставив беспрецедентные сведения о физиологических и поведенческих изменениях, связанных с рассеянным склерозом (РС), болезнью Альцгеймера (БА) и болезнью Паркинсона (БП). Цифровые биомаркеры, определяемые как объективные и количественные данные, полученные с помощью цифровых устройств, включают важные показатели, такие как скорость ходьбы и анализ движений. В этом исследовании демонстрируется, как цифровые биомаркеры могут раскрыть важную информацию о прогрессировании заболеваний, и подчеркивается интеграция технологий в клиническую практику как средство повышения качества ухода за пациентами. Изучая роль цифровых биомаркеров в контексте нейродегенеративных заболеваний, данная работа акцентирует внимание на потенциале улучшения точности диагностики и результатов лечения, что в конечном итоге ведет к улучшению качества жизни пострадавших.

Keywords: цифровые биомаркеры, рассеянным склерозом (РС), болезнью Альцгеймера (БА), болезнью Паркинсона (БП), скорость ходьбы и анализ движений.

Introduction

Neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease are diseases that are hard to cure and early diagnosis plays a crucial role for slowing down their symptoms. People who suffer from Alzheimer's disease and other neurodegenerative diseases have difficulties such as losing balance or coordination, feet shuffle and drag when they walk, inability to control muscle movements and being confused while talking. These hurdles give burden for patients and their caregivers [1]. The symptoms and progression of these diseases can vary from patient to patient and since there is no definite method for diagnosing these diseases, and the methods that are used to diagnose these are not enough to understand the progression of the diseases. Thus everyday gadgets such as phones, tablets, smart watches can be of great help for tracking the symptoms of these diseases by collecting signals from patients.

Digital biomarkers are defined as objective, quantifiable physiological and behavioral data collected via digital devices, which can provide critical insights into an individual's health status.

Among these, gait speed and movement analysis emerge as paramount indicators, especially in the context of neurodegenerative diseases such as Multiple Sclerosis (MS), Alzheimer's Disease (AD), and Parkinson's Disease (PD) [2]. These conditions are characterized by progressive neurological decline, often accompanied by impairments in motor function, cognitive abilities, and daily living activities. The utilization of digital biomarkers offers the potential for early detection, ongoing monitoring, and personalized interventions, thereby enhancing patient outcomes and quality of life. Advanced gait analysis techniques, including the use of motion sensors and pressure-sensitive insoles, enable healthcare professionals to capture detailed parameters such as stride length, cadence, and symmetry [3-6]. These technologies can identify deviations from normative gait patterns, providing invaluable data for clinicians to tailor interventions specific to individual patient needs. In patients with PD, for example, gait analysis can reveal characteristic features such as bradykinesia and postural instability, allowing for targeted rehabilitation strategies (Higgins et al., 2020).

Digital Biomarkers in Neurodegenerative Diseases: comparison and analysis

The application of digital biomarkers, particularly gait speed, step length, and movement analysis, in the diagnosis and management of neurodegenerative diseases is profoundly impactful [7]. These parameters provide crucial insights into mobility and functional limitations, allowing for early detection of neurodegeneration before clinical symptoms manifest. Subtle changes in these metrics can serve as warning signs of emerging neurodegenerative diseases, enabling timely diagnosis and intervention. For example, a reduction in gait speed or an increase in stumbling frequency may indicate underlying issues, prompting further evaluation and proactive management [8].

Tracking these parameters over time is vital for monitoring disease progression. Regular evaluations reveal how an individual's motor function changes, which is crucial for adjusting treatment plans and rehabilitation strategies. This ongoing monitoring ensures that interventions are tailored to the patient's evolving needs, optimizing outcomes. Moreover, assessing factors lie stride width and postural stability is key to understanding fall risk. Many individuals with neurodegenerative diseases experience balance impairments, making them more susceptible to falls [9]. By analyzing these aspects, clinicians can develop targeted strategies to enhance stability and reduce the likelihood of accidents, ultimately promoting safety and independence.

Table 1. Comparison of gait parameters between healthy individuals and neurodegenerative diseases

Parameter	Healthy individuals	Neurodegenerative patients
Gait speed (m/s)	1.2 – 1.5	0.5 – 1.0
Step length (cm)	70 – 80	50 – 60
Cadence (SPM)	110 – 130	80 – 100
Stride width (cm)	5 – 10	10 – 15
Postural stability	High	Low

Stumbling frequency adds another dimension to this analysis, providing insights into patient's coordination and overall stability. Analyzing stumbling frequency as a parameter between healthy individuals and those with neurodegenerative diseases is important to understand mobility and overall health. Stumbling frequency serves as a crucial digital biomarker, providing insights into balance, coordination and functional stability. Understanding when and how often stumbling occurs can help clinicians identify specific challenges, guiding therapeutic adjustments and daily activity recommendations that enhance mobility and confidence [10]. This dynamic evaluation is essential for optimizing care and ensuring that therapeutic approaches remain relevant to the patient's evolving condition.

Table 2. Comparison of stumbling frequency according to per hour between healthy individuals and neurodegenerative diseases

Group	Average stumbling frequency (stumbles per hour)	Standard Deviation	Notes
Healthy individuals	1 – 2	0.5	Represents typical range for healthy adults
Neurodegenerative patients	5 – 10	2.5	Reflects increased risk for stumbling

Table 3. Comparison of stumbling frequency according to per 100 times between healthy individuals and neurodegenerative diseases

Group	Stumbling frequency (per 100 times)	Notes
Healthy individuals	1 – 2	Reflects normal mobility patterns
Neurodegenerative patients	5 – 10	Indicates increased instability and fall risk

These comparisons provide quantitative baseline that helps healthcare professionals to identify deviations from typical mobility patterns. Early detection of increased motor function degradations can signal onset of neurodegenerative diseases, allowing for timely interventions. Recognizing these issues before they progress into more severe symptoms can lead to better management strategies and improved quality of life for patients.

Collecting Digital Biomarkers using wearable gadgets and smartphones: Implementation and Challenges

The collection of digital biomarkers through wearable gadgets and smartphones represents a significant advancement in the field of neurology, offering a practical means of obtaining continuous, real-time data that enhances clinical assessments [11]. Wearable devices such as smartwatches, fitness trackers, and specialized medical sensors can monitor various physiological and behavioral parameters, including heart rate, physical activity, and gait speed. The implementation of digital biomarker collection commences with the selection of appropriate devices capable of measuring relevant metrics such as heart rate, physical activity, sleep quality and gait patterns [12]. It is imperative that these devices be user friendly and compatible with smartphones to ensure seamless data integration. Effective data management is essential, necessitating systems that can aggregate information from various sources, including electronic health records (EHRs), to construct comprehensive health profiles [13]. Furthermore, the integration of artificial intelligence and machine learning algorithms in these applications can enhance data analysis, enabling the detection of patterns and trends that may not be apparent through traditional assessments. For instance, machine learning models can analyze collected motor function data to predict disease progression or response to therapy, allowing for personalized treatment approaches tailored to individual patients' needs [14]. This level of personalized care is particularly crucial for individuals with neurodegenerative diseases, where symptoms and disease trajectories can vary widely among patients.

Challenges

Despite the numerous advantages of digital biomarkers, several challenges must be meticulously addressed. Data privacy and security are of utmost importance, sensitive health information must be safeguarded. Furthermore, the accuracy and reliability of data collected through wearable devices can vary, necessitating regular calibration and validation against established clinical benchmarks [15]. Finally, the integration of digital biomarkers into existing clinical workflows requires comprehensive training for healthcare professionals, ensuring they are equipped to interpret the data effectively and incorporate it into patient care.

Conclusion

In conclusion, the integration of digital biomarkers, particularly gait speed and movement analysis, represents a significant advancement in the assessment and management of neurodegenerative diseases such as Multiple Sclerosis, Alzheimer's Disease, and Parkinson's Disease. The ability to collect and analyze these biomarkers using wearable gadgets and smartphone applications facilitates continuous monitoring, allowing for real-time insights into a patient's health status. As researches are conducted to underscore the importance of gait speed as a critical indicator of overall health and cognitive function, the role of movement analysis in diagnosing and managing neurodegenerative diseases becomes increasingly clear. The incorporation of these technologies into clinical practice not only enhances diagnostic accuracy but also empowers patients to take an active role in their health management, ultimately leading to improved quality of life and better healthcare outcomes.

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