# POSSIBILITY OF EARLY DETECTION OF PARKINSON'S DISEASE USING CONVOLUTIONAL NEURAL NETWORK DURING SIX-MINUTE WALK TEST

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This study aimed to determine the accuracy of distinguishing patients with early Parkinson's disease (PD) (n=27) from healthy controls (n=50) using a convolutional neural network (CNN) technique with an artificial intelligence deep learning algorithm based on a 6-minute walk test (6MWT) using wearable sensors. After wearing the six sensors, the participants performed the 6MWT, and the time-series data were converted into new images. The main results demonstrated the highest discrimination accuracy of 72% on the left arm gyroscope data. The results confirmed the possibility of using CNN models to distinguish between individuals with early PD and controls. Moreover, the 6MWT using sensors may contribute to early diagnosis as an objective indicator in clinical settings.

**KEYWORDS:** Parkinson's disease, deep learning, early detection, motor symptoms

**INTRODUCTION:** The heterogeneity of Parkinson's disease (PD) generates significant challenges for accurate diagnosis, especially in the early stages of the disease, when symptoms may be very subtle (De Lau & Breteler, 2006). The clinical severity of PD can be categorized into five stages known as the Hoehn-Yahr stages (H&Y stages I–V) (Hoehn & Yahr, 2001). In stage I, which includes patients in the early stage of this study, individuals may experience unilateral symptoms such as symmetrical movement reduction of one limb, asymmetrical hand movements, and shuffling when walking (Lin et al., 2022). However, identifying PD in the early stages is challenging, as the aging population, experiencing conditions such as joint osteoarthritis or sarcopenia, may also demonstrate a progressive decline in walking speed termed senile gait (Jahn, Zwergal, & Schniepp, 2010). To solve the above-mentioned issues, gait evaluation of individuals with PD using wearable sensors has been studied to detect and predict gait disturbance signals in daily life and clinical environments (Agurto et al., 2021). However, limitations still exist in identifying subtle early motor symptoms of PD, and identifying which body segments are best suited to detect early signals remains unclear.

The 6-minute walk test (6MWT) has been proposed as a simple, inexpensive, safe, reproducible, and alternative functional test for assessing functional aerobic capacity (Fuentes-Abolafio et al., 2024). Utilizing these advantages, a 6MWT with wearable sensors is both clinically applicable and comprehensive (Atri et al., 2022). The ability to detect a decline in motor performance during prolonged walking may aid in identifying subtle early motor characteristics in patients with PD (Angelini et al., 2020; Chandrabhatla et al., 2022). Recently, an increasing trend has been observed in the use of artificial intelligence-based machine and deep learning models to classify and predict PD. In particular, researchers have focused on improving the classification of motor symptom severity based on body segment manifestation sites using data combined with the comprehensive gait characteristics of individuals with PD (Kim et al., 2018; Alaskar et al., 2020; Balaji et al., 2021; El Maachi et al., 2020). For objective gait disorder signal detection, the accuracy can be improved using time-series gait patterns and classifying them into visual images using convolutional neural networks (CNNs) (Ramanujam et al., 2021). However, no study has used this CNN technique to classify patients with early PD during the 6MWT.

Therefore, our study aimed to explore the classification of individuals with PD in the early stage (H&Y stage I) and healthy controls through the 6MWT using a wearable sensor-based artificial intelligence deep learning algorithm.

**METHODS:** The participants were patients diagnosed with idiopathic PD, based on the criteria provided by the United Kingdom's Parkinson's Disease Society Brain Bank. This study recruited 27 patients with H&Y stage I PD and 50 age-matched healthy controls. The participants could walk independently without assistive devices. All experiments in people with PD were performed in the "On" state of medication. Participants performed the 6MWT, in which they were instructed to walk as far as possible without running for 6 min. The 20-meter course was defined by cones at each end. Before initiating the task, the wearable sensors were attached to the left and right upper arms, thighs, thoracic spine, and lumbar spine.
Data were collected using an Xsens DOT Wearable Sensor platform (Movella Technologies, Enschede, Netherlands). The data output rate was set to 60 Hz. Three-dimensional data were collected using an iPad with the MovellaDOT app and analyzed using MATLAB R2021b (MathWorks, Natick, MA, USA). The resulting values of the acceleration and gyroscope data were used to analyze the time-series data. Six minutes (360 s) of time-series data from each participant's six sensors were split into 15-second segments, encompassing both straight and turning walking.
Statistical analyses were performed using MATLAB and Python (Python 3.10; Python Software Foundation). Normality tests for demographic and clinical information were performed using the Shapiro-Wilk test. Here, is the process of converting images from the time-series data. Acceleration and gyroscope data of 24 phases (6 min divided into 15 s) were used to analyze the time-series data. Following the conversion to a matrix form using time-series data from each phase, the converted data are generated in the new imaging. The process for determining the performance of a deep learning model based on imaging is illustrated below. The process was sampled using the accumulated imaging dataset from all the phases by randomly dividing it into training set (50%), validation set (20%), and testing set (30%). By performing 5-fold cross-validation, we ensured the generalization of the dataset and prevented overfitting of the network. The model is trained using a CNN technique, which is a type of deep neural network. The architecture of the model is illustrated in Figure 1. The performance of the two-group classification model is evaluated based on its accuracy.

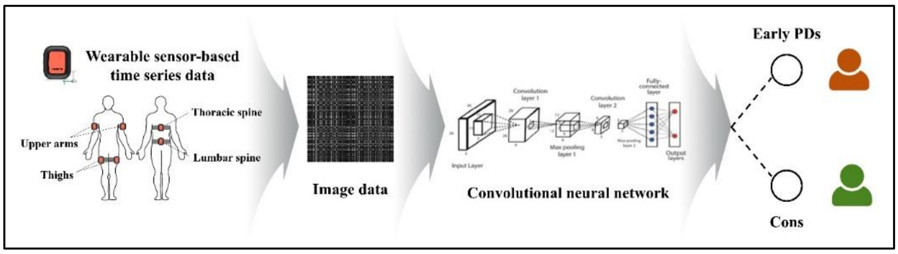


**Figure 1: Architecture of the convolutional neural network model.**
**PD: Parkinson's disease; Cons: controls**

**RESULTS:** The demographic and clinical characteristics of the study population are summarized in Table 1. We conducted this study to first screen for motor symptoms of PD using acceleration and gyroscope data from wearable sensors at six body segment locations. Individuals with PD and healthy controls could be classified with an accuracy of 0.55 for the left arm, 0.56 for the right arm, 0.63 for the thoracic spine, 0.60 for the lumbar spine, 0.54 for the left thigh, and 0.54 for the right thigh in the acceleration data. Regarding the gyroscope data, accuracies of 0.72, 0.58, 0.65, 0.64, 0.52, and 0.58 were obtained for the left arm, right arm, thoracic spine, lumbar spine, left thigh, and right thigh, respectively. Additionally, Figure 2 displays the confusion matrix obtained by training ResNet to produce the most accurate results for classifying patients with PD and healthy controls.

**Table 1: Demographic and clinical characteristics of all participants.**

| | Individuals with PD (n=27) | Controls (n=50) |
|---|---|---|
| Sex (male/female) | 11 / 16 | 21 / 29 |

| | | |
|---|---|---|
| Age (years) | 67.71 ± 7.21 | 65.80 ± 5.51 |
| Height (cm) | 160.55 ± 8.20 | 161.14 ± 8.38 |
| Body mass (kg) | 63.36 ± 10.76 | 63.68 ± 10.04 |
| BMI (kg/m$^2$) | 24.45 ± 2.96 | 24.40 ± 2.43 |
| MMSE (scores) | 27.83 ± 2.10 | 27.22 ± 1.90 |
| UPDRS Total (scores) | 53.79 ± 23.08 | - |
| UPDRS III (scores) | 29.01 ± 15.28 | - |

PD: Parkinson's disease; BMI: body mass index; MMSE: Mini Mental State Examination; UPDRS: Unified Parkinson’s Disease Rating Scale.

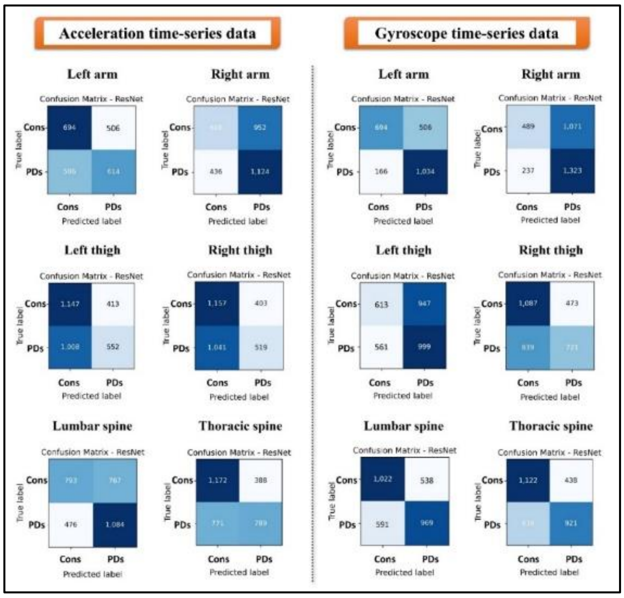


**Figure 2: Confusion matrices obtained by training ResNet for accuracy of results.**
**PD: Parkinson’s disease; Cons: controls**

**DISCUSSION:** This study investigated the possibility of early detection of PD. We used the data measures of the 6MWT to train CNN models that could detect and classify PD based on the participants’ motion data obtained using wearable sensors. We found the highest discrimination accuracy of 72% on the left arm gyroscope data. In the previous study, data analysis using wearable sensor-based machine learning methods (feature extraction, dimensionality reduction, classification) helped to significantly improve the diagnostic accuracy of PD in early stages, showing F1-micro scores of 0.78 and 0.88 for H&Y stages 1 and 2, respectively (Shcherbak et al., 2023). Another study proposed a tremor assessment system that utilizes CNN technology and accelerometer and gyroscope signals from a single sensor to quantify the severity of PD (Kim et al., 2018). However, to our knowledge, no study has used this CNN technique to classify early PD patients according to symptom severity during the 6MWT, which includes both straight and turning gait. Subjective assessment by neurologists scoring through clinical observation has relatively low reliability and validity, so early detection of PD remains ambiguous and challenging in clinical settings (Rizzo et al., 2016). Our study confirmed the potential for early detection when applying CNN deep learning models, with an accuracy of 52% to 72% in classifying early PD and controls. In particular, we found the highest discrimination accuracy on the left arm gyroscope data (72%). These results support the finding that in H&Y stage 1, patients with PD may experience unilateral symptoms such as asymmetric hand tremors, especially when walking (Lin et al., 2022). Future large-scale studies enrolling more patients with PD are needed to validate the effectiveness of these models. Nevertheless, our findings suggest that the 6MWT and CNN models may help physicians diagnose PD at an early stage, allowing timely treatment within the golden time window for the transition from geriatric to pathological gait patterns.

**CONCLUSION:** In our study, CNN analysis was performed by imaging time series data from the sensors and was able to distinguish early PD from healthy controls with the highest accuracy of 72% for gyroscope data from the left arm. Although these results are limited in terms of classification performance, we suggest that two-dimensional imaging as a method for analyzing infinite-length one-dimensional time series data may provide an opportunity to screen gait patterns of early-stage PD patients for primary classification. Furthermore, if sufficient samples are available, the CNN model can be applied to classify other diseases, such as benign tremors, in patients with early PD. Future research should focus on identifying machine learning-based features or biomarkers using signal processing analysis for early diagnosis of PD.

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