Özgün Araştırma / Original Research

# PARKİNSON HASTALARINDA SENSÖR TEMELLİ YÜRÜME ANALİZİ

# SENSOR-BASED GAIT ANALYSIS IN PATIENTS WITH PARKINSON'S DISEASE

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## ÖZET

Yürüyüş bozukluğu Parkinson hastalığının (PH) temel semptomlarından biridir. Bu çalışmanın amacı PH hastalarında atalet sensörleri kullanarak yürüme parametrelerini, hastalık şiddeti ile yürüme parametreleri arasındaki ilişkiyi araştırmaktır. PH tanısı almış 18 hastaya iki dakika yürüme testi yapıldı. Yürüme parametreleri incelendi ve yürüme parametrelerinin MDS-UPDRS Bölüm III ve Hoehn &Yahr (H&Y) ölçeği puanları ile ilişkisi araştırıldı. Çalışmaya yaş ortalaması 65.78 ± 8.07 olan 18 PH tanılı hasta (8 kadın, 10 erkek) dahil edildi. Ayak vuruş açısı (r=-0.66), dönüş açısı (r=-0.73), adım uzunluğu (r=-0.52) ve dönüş hızı (r=-0.54) MDS-UPDRS bölüm III skoru ile negatif, dönüş süresi (r=0.58) ile pozitif korelasyon gösterdi ($p<0.05$). H&Y evrelemesi, ayak vuruş açısı (r=-0.58), parmak uç açısı (r=-0.53) ile negatif, dönüş süresi (r=0.56) ve dönüş hızı (r=-0.52) ile pozitif korelasyon gösterdi. Atalet sensörleri ile Parkinson hastalarının klinik değerlendirmesini destekleyen objektif yürüyüş parametreleri sağlanabilir.

**Anahtar Kelimeler:** Parkinson hastalığı, Yürüme analizi, Atalet sensörleri, APDM

## ABSTRACT

Gait impairment is one of the cardinal signs of Parkinson disease (PD). This study aims to investigate gait parameters using inertial sensors and evaluate the relation between disease severity and gait parameters. Two-minute walkway tests were performed on 18 patients with PD. Gait parameters were analyzed and the relation between gait parameters and the scores of MDS-UPDRS Part III and the Hoehn &Yahr (H&Y) scale is investigated. 18 PD patients (8 female, 10 male) with a mean age of 65.78 ± 8.07 were included in the study. Foot strike angle(r=-0.66), turn angle (r=-0.73), stride length (r=-0.52), and turn velocity (r=-0.54) showed negative, turn duration (r=0.58) showed a positive correlation with the score of MDS-UPDRS part III, ($p<0.05$). H&Y staging showed a negative correlation with foot strike angle (r=-0.58), toe off angle (r=-0.53), and turn velocity (r=-0.52), a positive correlation with turn duration (r=0.56). Inertial sensors may provide objective gait parameters supporting the clinical assessment of patients with PD.

**Keywords:** Parkinson's disease, Gait analysis, Inertial sensors, APDM

## INTRODUCTION

Parkinson's disease (PD) is the most common movement disorder characterized by motor and non-motor symptoms. Bradykinesia, rigidity, postural instability and tremor are the cardinal motor symptoms of this chronic neurodegenerative disease (Poewe et al., 2017). Gait disturbance is one of the major devastating motor symptom contributing to the falls in patients with PD (Lai et al., 2022). Current treatment is based on symptom alleviation. Clinical features of the patients need to be meticulously assessed and monitored for an individual optimized treatment.

Movement Disorder Society Unified Parkinson's disease Rating Scale (MDS-UPDRS)



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is the major validated clinical scale widely being used by clinicians to asses clinical features and the severity of the disease (Goetz et al., 2009). However, it may inherit some limitations such as intra and inter-rater variability and may not show small alterations within patients (Merola et al., 2018). More objective and quantitative measures are needed.

Instrumented gait analysis may objectively analyze gait and balance improvements and reveal features that are not commonly available through clinical observations or assessments (Agostini et al., 2015). The Ambulatory Parkinson's Disease Monitoring (APDM) inertial sensor (Opals and Mobility Lab) is a wearable system that includes three-axis accelerometers, gyroscopes, and a magnetometer (Fang et al., 2018; Mancini and Horak, 2016). Digital measurements of spatiotemporal and dynamic gait parameters such as stride length, step width, step length, gait velocity derived from APDM inertial sensor may provide less observational bias in clinical assessment and detect small changes in patients' motor symptoms.

The aim of this study is to investigate gait parameters using APDM inertial sensor and evaluate the relation between disease severity and gait parameters.

## METHODS

A total of eighteen patients with a diagnosis of PD based on international recognized criteria from the neurology department at Koç University Hospital were included. All patients participated voluntarily and gave written informed consent. Demographic data, including age, gender as well as information on disease duration were collected. In this study, MDS-UPDRS Part III is used. The MDS-UPDRS is a clinical scale with 4 subscales. Part I - non-motor experiences of daily living including 13 items; Part II – motor experiences of daily living including 13 self-reported items; Part III – motor examination including 18 items (33 scores); and Part IV - motor complications including 6 items assessed in a semi-structured interview (Goetz et al., 2008). All the items are scored on a scale from 0 (normal) to 4 (severe), total scores are obtained from the sum of the corresponding item scores. The disease stage was assessed by the Hoehn & Yahr scale (H&Y) included in the MDS -UPDRS. All patients were invited to the Motion Analysis Laboratory. They performed 2 Minutes Walking Test (2 MWT) with APDM Mobility Lab System (APDM Inc., Portland, OR, USA). Participants wore three OPAL sensors on their feet and lumbar area to assess spatiotemporal parameters, trunk angles, turning angles, and velocity during the gait task. Patients performed 2 MWT on a 10-meter back-and-forth walkway at an average speed. Gait parameters were documented according to the APDM Mobility Lab Guidelines.

Continuous variables were presented as median (interquartile range), and categorical variables as numbers and percentages. Correlation analysis were performed for gait parameters and the scales. Graphpad Prism software 8.4.3 (GraphPad Software Inc., La Jolla, CA, USA). Normality assumptions were performed with Anderson-Darling and D'Agostino& Pearson tests. The Pearson correlation test was used to see the correlation between the dependent gait data and UPDRS and H&Y

## RESULTS

Eighteen patients with PD (8 female, 10 male) with a mean age of 65.78 ± 8.07 were included in the study. The demographic and clinical features of the patients are shown in Table 1.

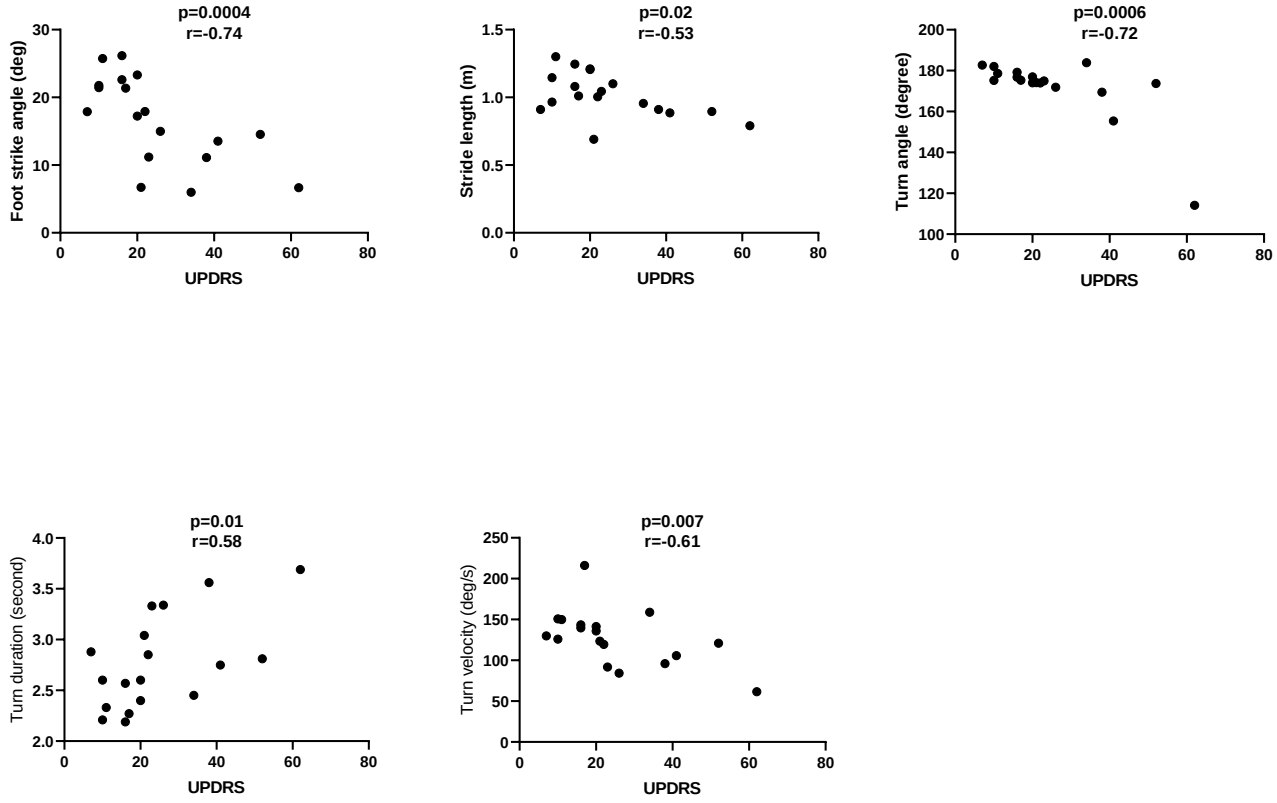
**Table 1:** Demographic and clinical features of the patients.

| **Parameters** | **Patients (n=18)** |
|---|---|
| **Age, years Mean ± SD** | 65.78 ± 8.07 |
| **Female / Male** | 8 (44%) / 10 (56%) |
| **Duration of disease, years Mean ± SD** | 4.55 ± 4.07 |
| **MDS-UPDRS-III Median (IQR)** | 20 (13.5-30) |
| **H&Y Median (IQR)** | 2 (1-2) |

*Abbreviations: IQR, interquartile range; SD, standard deviation; n, number.*

Foot strike angle(r=-0.66), turn angle (r=-0.73), stride length (r=-0.52), turn duration (r=0.58) and turn velocity (r=-0.54) were strongly correlated with MDS-UPDRS part III, ($p<0.05$). H&Y staging showed a moderate correlation with foot strike angle (r=-0.58), toe off angle (r=-0.53), turn duration (r=0.56), and turn velocity (r=-0.52), Figure 1. All analyzed gait parameters are summarized in Table 2.

**Figure 1.** Spearman's correlation analysis of MDS-UPDRS Part III with gait parameters.




The mean values of measurements done for each participant are shown as dots. ** refers to p<0.01.

**Table 2:** Correlation of MDS-UPDRS Part III and H&Y Scale with gait parameters of PD patients.

| | **Patients' Values** | **APDM Normative Range** | **P value (correlation with UPDRS)** | **P value (correlation with H&Y)** |
|---|---|---|---|---|
| **Cadence, step/min Mean ± SD** | 102.2 ± 13.26 | 103-133 | ns | ns |
| **Gait speed, m/s Mean ± SD** | 0.874 ± 0.19 | 1.04-1.64 | ns | ns |
| **Stride length, m Mean ± SD** | 1.01 ± 0.16 | 1.11-1.66 | ns | ns |
| **Step time, s Mean ± SD** | 0.598 ± 0.07 | 0.450-0.580 | ns | ns |
| **Stride time, m Mean ± SD** | 1.19 ± 0.15 | 0.900-1.16 | **0.02** | ns |
| **Stance phase, GCT% Mean ± SD** | 61.12 ± 1.71 | 56.1-62.3 | ns | ns |
| **Swing phase, GCT% Mean ± SD** | 38.88 ± 1.71 | 37.7-43.9 | ns | ns |
| **Double support phase, GCT% Mean ± SD** | 22.27 ± 3.45 | 12.4-24.6 | ns | ns |
| **Terminal double support phase, GCT% Mean ± SD** | 11.15 ± 1.70 | 6.14-12.1 | ns | ns |
| **Single limb support, GCT% Mean ± SD** | 38.85 ± 1.73 | | ns | ns |
| **Elevation at midswing, cm Mean ± SD** | 1.77 ± 0.86 | 0.370-2.40 | ns | ns |

| | | | | |
|---|---|---|---|---|
| **Lateral step variability, cm Mean ± SD** | 2.53 ± 0.64 | 2.22-4.53 | ns | ns |
| **Circumduction, cm Mean ± SD** | 3.07 ± 1.10 | 1.97-6.13 | ns | ns |
| **Foot strike angle, degree Mean ± SD** | 16.67 ± 6.49 | 16.5-33.2 | **0.002** | **0.01** |
| **Toe-off angle, degree Mean ± SD** | 33.40 ± 3.63 | 32.9-45.8 | ns | **0.02** |
| **Toe out angle** | 13.05 ± 5.40 | -1.30-19.3 | ns | ns |
| **Lumbar Coronal ROM, degree Median (IQR)** | 6.99 (5.69-12.11) | 4.90-13.7 | ns | ns |
| **Lumbar Sagittal ROM, degree Median (IQR)** | 5.10 (4.02-5.93) | 2.88-9.71 | ns | ns |
| **Lumbar Transverse ROM, degree Mean ± SD** | 9.19 ± 3.53 | 5.20-18.8 | ns | ns |
| **Turn angle, degree Median (IQR)** | 175.1 (173.2-178.8) | 170-188 | **0.005** | ns |
| **Turn duration, s Mean ± SD** | 2.77 ± 0.46 | 1.82-2.92 | **0.01** | **0.01** |
| **Turn velocity, degree/s Mean ± SD** | 127.5 ± 33.97 | 126-260 | **0.01** | **0.02** |

Significant p-values are shown in bold.
Abbreviations: IQR, interquartile range; GCT, gait cycle time; ROM, range of motion; SD, standard deviation.

## DISCUSSION

Wearable inertial sensors are portable, compact systems that are simple to operate. A growing body of evidence shows that portable systems are effective tools for gait analysis (Muro-de-la-Herran et al., 2014). Additionally, the quantitative analysis of gait data reveals modest alterations in gait that could be quite helpful in the evaluation of PD patients.

It has been demonstrated that clinical disease severity is associated with reduced stride length and speed during cycle (Lai et al., 2022). Here, our results also supported that the score of MDS-UPDRS-Part III showing disease severity is in correlation with foot strike angle, turn angle, strike length, turn duration and turn velocity. In addition, gait parameters such as foot strike angle, toe off angle, turn duration and turn velocity were also found to be in correlation with H&Y staging of the patients. Clinical assessment of disease severity may be strengthened with using such parameters that can provide a scientific basis for a close follow-up of patients.

Moreover, several studies have investigated gait parameters in other cohorts with gait impairment such as atypical parkinsonian syndromes and concluded that sensor-based technology may support the clinical assessment obtained by clinical scales (Hausdorff et al., 1998; Na et al., 2019; Raccagni et al., 2018). In this study, we only focused in patients with PD. Identifying gait parameters in different patient cohorts may provide a valuable clue to use in distinguishing PD patients with gait disturbances and patients with gait disturbances associated other diseases.

## STUDY LIMITATIONS

The main limitations of this study are the small sample size and the lack of a control group. Furthermore, we included patients only in the early stage of PD. Thus, further studies in larger patient populations including late-stage of PD patients may provide more objective parameters to use in managing patients in daily practice as well as clinical trials.

## ETHICS COMMITTEE APPROVAL

This study was approved by the Local Ethics Committees at Koç University

## CONCLUSION

Sensor-based gait analysis of patients with PD may improve the clinical assessment of patients with providing quantitative measurements. Capturing small differences in gait parameters may be valuable especially for clinical trials in PD patients.

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