Assessment of Motor Impairments in Early Untreated Parkinson's Disease Patients: The Wearable Electronics Impact

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***Abstract*—*Objective:* The complex nature of Parkinson's disease (PD) makes difficult to rate its severity, mainly based on the visual inspection of motor impairments. Wearable sensors have been demonstrated to help overcoming such a difficulty, by providing objective measures of motor abnormalities. However, up to now, those sensors have been used on advanced PD patients with evident motor impairment. As a novelty, here we report the impact of wearable sensors in the evaluation of motor abnormalities in newly diagnosed, untreated, namely *de novo*, patients. *Methods:* A network of wearable sensors was used to measure motor capabilities, in 30 *de novo* PD patients and 30 healthy subjects, while performing five motor tasks. Measurement data were used to determine motor features useful to highlight impairments and were compared with the corresponding clinical scores. Three classifiers were used to differentiate PD from healthy subjects. *Results:* Motor features gathered from wearable sensors showed a high degree of significance in discriminating the early untreated *de novo* PD patients from the healthy subjects, with 95% accuracy. The rates of severity obtained from the measured features are partially in agreement with the clinical scores, with some highlighted, though justified, exceptions. *Conclusion:* Our findings support the feasibility of adopting wearable sensors in the detection of motor anomalies in early, untreated, PD patients. *Significance:* This work demonstrates that subtle motor impairments, occurring in *de novo* patients, can be evidenced by means of wearable sensors, providing clinicians with instrumental tools as suitable supports for early diagnosis, and subsequent management.**

***Index Terms*—IMU, machine learning, motion analysis, parkinson's disease, signal processing, wearable technology.**

I. Introduction

IDIOPATIC Parkinson disease (PD) is the second most common neurodegenerative disorder with an estimated 4 million patients worldwide. It is a progressive and complex multisystem disorder affecting vulnerable populations, whose prevalence is expected to double by 2030 [1]. The main clinical phenotype consists of motor symptoms such as bradykinesia, rest tremor, rigidity, postural and gait disturbances.

Bradykinesia is defined as slowness of movements; it is the cardinal motor manifestation of PD, and is relevant in the diagnosis of Parkinsonian syndrome [2]. Rest tremor refers to a 4–6 Hz tremor in the fully resting limb, suppressed during movement initiation. Rigidity refers to the resistance encountered during a passive movement of a major body joint. Postural instability is characterized by large postural sway during standing balance, by falling, by ineffective postural response to external perturbations and difficulty in changing motor programs. Lastly, the Parkinsonian gait is characterized by postural abnormalities, reduced arm swing, short steps, slowness and, in the later phases of disease, freezing.

However, clinical manifestations may be quite heterogeneous, with a different combination of both motor and non-motor features of the disease [3]. For this reason, clinical evaluation of disease progression is not trivial for neurologists.

At present, clinical evaluation of PD's motor symptoms is obtained by means of a standardized rating scale, the Unified Parkinson's Disease Rating Scale (UPDRS) [4]. However, there are limitations in the usefulness of this rating instrument. The assessment of the disease is still error prone due to personal interpretations and experience, so that the ratings can vary across raters and for an individual scorer at different times [5]. Furthermore, the discrete nature of the UPDRS hardly allows detecting subtle changes during the disease progression, mainly due to human visual capabilities and perceptual bias.

In such contest, different technologies have been introduced to objectively measure human motor abilities and capabilities in the medical field [6], [7]. RGB cameras [8], [9], electromyography [10]–[14], inertial sensors [15]–[18], balance board [19]–[21], and smartphones [22], [23] were used to provide quantitative measures in PD. Among them, wearable sensors (wearables hereafter) have been increasingly adopted in determining PD's motor severities, addressing the shortcomings of the current rating scale.

In particular, the bradykinesia has been mainly assessed by correlating motor features obtained from wearables to the UPDRS score. For example, Kim *et al*. [24] and Heldman *et al*. [25]

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