Quantitative assessment of forearm pronation/supination motor functions using a smartphone accelerometer for an early diagnosis of Parkinson’s disease

Ji Hun Choi1, Yun Joong Kim2, Hyeo-Il Ma3 and Unjoo Lee1,*

1Department of Electrical Engineering, Hallym University, 1 Hallymdaehak-gil, Chuncheon, Gangwon-do, Republic of Korea
2Department of Neurology, Hallym University Sacred Heart hospital, Hallym University College of Medicine, Anyang, Republic of Korea
3Department of Neurology, Hallym University Sacred Heart hospital, Hallym University College of Medicine, Hallym University

wlgn203@gmail.com, {yunkim, hima, ejlee}@hallym.ac.kr

Abstract. A series forearm pronation and supination motor task, FPSMT is developed to quantitatively assess various primary motor symptoms such as resting tremor, bradykinesia, rigidity and posture disturbance using an accelerometer built in a smartphone, which is portable and comfortable and cost effective. The FPSMT has two procedures of tasks, “Flat” and “Up” according to the initial forearm postures. The result from thirty three subjects including six PD patients showed reasonable sensitivities and specificities.

Keywords: Parkinson’s disease, motor symptom, accelerometer, sensor

1 Introduction

Parkinson’s disease (PD), a progressive neurological disorder resulting from the degeneration of dopamine producing neurons within midbrain or mesencephalon affects an individual’s quality of life with common symptoms such as akinesia, bradykinesia, hypokinesia, postural instability, rigidity and resting tremor. There are several drugs such as Carbidopa/Levodopa and Dopamine agonists and surgical procedures such as deep brain stimulation developed for symptomatic or neuroprotective therapies and long-term motor improvement treatment, respectively. However, proper medical care of these patients does not exist due to the progressive nature of the disease. It needs a convenient and technical method to record daily data of medications and motor symptoms related to progressive neurological disorder to provide an early diagnosis and a properly personalized medical treatment of PD.

Developing sensor and smartphone application technologies could address these requirements in terms of keeping tracking individuals with PD under varied and indoor/outdoor circumstances and analyzing their daily data to make a quantitative assessment. Especially, smartphone sensors such as accelerometers and gyroscopes
can provide information regarding the patient’s movement status such as displacement, velocity, angular velocity, acceleration, etc. Robert LeMoyne et al. presented a wireless accelerometer configuration with glove mounted setup for monitoring simulated PD hand tremor [1]. Siddharth Arora et al. quantified gait and postural sway of PD by extracting features in time and frequency domains of data obtained from accelerometers built in a smartphone [2]. Kun-Chan Lan et al. proposed a PDR-based method to continuously monitor and record the patient’s gait characteristics using a smart-phone [3]. N. Kostikis, et al. compared quantitative measurements, which are four metrics obtained by using smartphone-based platform, of hand tremor in twenty-three PD patients with Unified Parkinson’s Disease Rating Scale (UPDRS) [4]. However there still are none method to detect various symptoms of PD. Alexandros T. Tzallas, et al. developed an intelligent closed-loop system, PERFORM for remotely monitoring, assessment and management of patients with PD consisting of wearable multi-sensor monitor unit, the local base unit and the centralized hospital unit and using a wide range wearable sensors to evaluate and quantify the PD motor symptoms related to end of dose deterioration such as tremor, bradykinesia, and freezing of gait as well as those related to over-dose concentration such as Levodopa-induced dyskinesia[5]. But the system PERFORM has lack of portability and comfort in use and expensive.

In this study, a series forearm pronation and supination motor task, FPSMT is developed to quantitatively assess various primary motor symptoms such as resting tremor, bradykinesia, rigidity and posture disturbance using an accelerometer built in a smartphone, which is portable and comfortable and cost effective. The FPSMT has two procedures of tasks, “Flat” and “Up” according to the initial forearm postures. The result from thirty three subjects including six PD patients showed reasonable sensitivities and specificities, suggesting that FPSMT could be used to collect forearm motor related information on a daily basis allowing for the use in early diagnosis of patients with PD and also in constantly informing to the physician about the patient’s clinical state so as to readjust appropriately the treatment plan personalized and minimizing the side effects.

2 Materials and Methods

2.1 The FPSMT task

Figure 1 shows a protocol of the experiments UP and Flat of the FPSMT task. The FPSMT task consists of a series of four tasks of resting, LRRR proSupino, LRR proSupino and LR proSupino for the condition UP of the initial forearm posture or seven tasks of resting, BendingUp, BendingUp and Supination, BendingUp and Pronation, LRRR proSupino, LRR proSupino and LR proSupino tasks for the condition Flat of the initial forearm posture. The initial forearm posture of the condition Flat is supinated with both of its elbow and palm on the table. The initial forearm posture of the condition Up is neutralized and bended up with its elbow at the level of its shoulder. The LRRR proSupino task is for a subject to pronate and
supinate the lower arm in turns for 30 sec and there are 2 sec holding time between the turns. The LRR proSupino task is similar to the LRRR proSupino task except that there are 2 sec holding time every pronation and supination cycles. The LR proSupino task is for a subject to pronate and supinate the lower arm consecutively without holding time.

![Fig.1. The paradigms of the experiments UP and Flat of the FPSMT task.](image)

### 2.2 Data Collection

A controlled study was conducted with thirty three subjects. Six of them (four male and two female, mean 65 years) were diagnosed with PD, nine of them (seven male and two female, mean 64 years) were healthy with age-matched and no PD symptoms and eighteen of them (nine male and nine female, mean 24 years) were healthy young subjects. All the subjects were right-handed. The subjects with PD were classified according to the UPDRS. This study was reviewed by an institutional review board and an informed consent was provided from all the subjects.

Three axial accelerometer sensors built in an android smartphone grabbed by and on a given position of the right hand of a subject were used to record the activities during the tasks the subject was carrying out.

### 3 Results

Table 1 shows the performance measures, sensitivity and specificity for the assessment algorithm developed in this study using results obtained from thirty three subjects including six PD patients and compared to UPDRS scores. The results show 85.63 % and 89.07 % of mean sensitivities and specificities, respectively in scaling of the primary motor symptoms. It suggests FPSMT could be used to collect forearm motor related information on a daily basis allowing for the use in early diagnosis of patients with PD and also in constantly informing to the physician about the patient’s clinical state so as to readjust appropriately the treatment plan personalized and minimizing the side effects.
4 Conclusions

A series forearm pronation and supination motor task, FPSMT is developed to quantitatively assess various primary motor symptoms using an accelerometer built in a smartphone, which is portable and comfortable and cost effective. The results from thirty three subjects including six PD patients showed reasonable sensitivities and specificities, which suggests could be used to collect forearm motor related information on a daily basis allowing for the use of FPSMT in early diagnosis of patients with PD and for the treatment plan adjustment in a personalized way.

Table 1. The Sensitivity and specificity for the assessment algorithm developed in this study using results obtained and compared to UPDRS scores.

<table>
<thead>
<tr>
<th>Symptom (UPDRS compared)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
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<tbody>
<tr>
<td>resting tremor (20)</td>
<td>87.5</td>
<td>92.0</td>
</tr>
<tr>
<td>Bradykinesia (24,25,31)</td>
<td>100.0</td>
<td>88.8</td>
</tr>
<tr>
<td>Rigidity (22)</td>
<td>75.0</td>
<td>75.0</td>
</tr>
<tr>
<td>posture disturbance (30)</td>
<td>80.0</td>
<td>89.28</td>
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</tbody>
</table>

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References