COVID-19

Remote smartphone gait monitoring and fall prediction in Parkinson's disease during the COVID-19 lockdown

Massimo Marano[1] · Francesco Motolese[1] · Mariagrazia Rossi[1] · Alessandro Magliozzi[1] · Ziv Yekutieli[2] ·
Vincenzo Di Lazzaro[1]

Abstract

Background Falls could be serious events in Parkinson's disease (PD). Patient remote monitoring strategies are on the raise and may be an additional aid in identifying patients who are at risk of falling. The aim of the study was to evaluate if balance and timed-up-and-go data obtained by a smartphone application during COVID-19 lockdown were able to predict falls in PD patients.

Methods A cohort of PD patients were monitored for 4 weeks during the COVID-19 lockdown with an application measuring static balance and timed-up-and-go test. The main outcome was the occurrence of falls (UPDRS-II item 13) during the observation period.

Results Thirty-three patients completed the study, and 4 (12%) reported falls in the observation period. The rate of falls was reduced with respect to patient previous falls history (24%). The stand-up time and the mediolateral sway, acquired through the application, differed between "fallers" and "non-fallers" and related to the occurrence of new falls (OR 1.7 and 1.6 respectively, $p < 0.05$), together with previous falling (OR 7.5, $p < 0.01$). In a multivariate model, the stand-up time and the history of falling independently related to the outcome ($p < 0.01$).

Conclusions Our study provides new data on falls in Parkinson's disease during the lockdown. The reduction of falling events and the relationship with the stand-up time might suggest that a different quality of falls occurs when patient is forced to stay home — hence, clinicians should point their attention also on monitoring patients' sit-to-stand body transition other than more acknowledged features based on step quality.

Keywords Falls · Parkinson's disease · Gait · Timed-up-and-go test · Remote patient monitoring · Sensors

Introduction

Falls are leading causes of morbidity and poor quality of life, particularly in Parkinson's disease (PD) [1]. About 35–90% of PD patients experience a fall during the course of the disease and 70% of them will fall again — constituting a milestone in disease progression [1, 2].

Different PD fall risk factors have been identified — such as inaccurate stepping or disease severity [3]. Fall prevention is of the utmost importance and new technologies — as

wearable sensors — offer the chance to augment the ability to detect and track the fall risk [1, 3]. The use of sensors has been applied mainly in controlled laboratory setting, so far. In particular, inertial sensors have been used in different neurological disorders to objectively assess static and dynamic balance, but the large amount of data that they are able to provide are not commonly applied in routine clinical practice [3].

Coronavirus disease-2019 (COVID-19) posed a great challenge on neurological patients [4] and the restrictive measures to limit the spread of the infection had the unexpected twist of accelerating the use of digital health, remote patient monitoring strategies, teleneurology, and even remote rehabilitation programs [5, 6]. In this regard, sensors had already been proved to be a robust tool in identifying the various kinematic risk factors for falling [3]; therefore, wearables and sensors embedded in smartphones may be

✉ Massimo Marano
   m.marano@unicampus.it; masmarano@gmail.com

[1] Neurology, Neurophysiology and Neurobiology Unit,
   Department of Medicine, Università Campus Bio-Medico Di
   Roma, Viale Alvaro del Portillo, 21, 00128 Rome, Italy

[2] Montfort Brain Monitor, Binyamina, Israel

helpful to stratify the risk of falling of PD patients. Hence, we aimed to investigate for falling predictors on a cohort of PD patients enrolled in a prospective studied providing smartphone-derived kinematic gait data [5].

Methods

This is a post hoc analysis of the data obtained in a prospective 4-week observational study performed during the 2020 lockdown. Patients performed a series of motor tasks — including the 3-m timed-up-and-go test (3mTUG) and a static balance test — through the Encephalog application, as described elsewhere [5]. Patients also answered a "Parkinson status" question (motor self-evaluation, ranging 1–5). Only subjects who played the app at least once a week for the entire observational period were included ($n = 33$). Mean values for each 3mTUG parameter during the monitoring were adopted for the final analysis. A score ≥ 1 at the UPDRS-II item 13 ("falling unrelated to freezing"), referred to the observation period, was considered as the main endpoint [5]. The number of fall episodes was not collected due to the study design. In the pursue of fall predictors, we included in the analysis also patients' last UPDRS-III, Hoehn and Yahr, disease duration, and demographic parameters. All this data were recorded before the lockdown and assessed as not far as 3 months before the enrollment. Data are reported as median and quartiles (I–III) or frequencies and inferential statistics have been carried out by the Wilcoxon test or the chi-squared test. The correlation among variables has been investigated through logistic regression, odds ratio on tenths of seconds or centimeters for time and space variables respectively.

Results

At a baseline analysis, four patients out of 33 (12.1%) scored ≥ 1 at UPDRS-II item 13 at the study closure. In particular, 2 patients reported a score of 1 ("rare falling"), 1 patient reported a score of 2 ("occasional falls, less than once per day"), and 1 patient reported a score of 3 ("falls an average of once per day"). The "fallers" group had a significantly higher baseline UDPRS-II total and item 13 score than the "non-fallers" group. The other features were similar across groups (Table 1). On average, all subjects performed the tests in an efficient motor condition (median PD status during the test equal to 3.15, 2.45–4) and groups significantly differed for smartphone-derived gait data. The "fallers" showed a longer stand-up time and a higher magnitude of mediolateral sway at the 3mTUG than the "non-fallers" patients. There were no differences across groups in the other 3mTUG parameters and in the static balance examination (Table 2). At a univariate logistic regression analysis, the baseline UPDRS-II item 13 was associated with the occurrence of new falls (R^2 0.422, OR = 7.5,

$p = 0.01$), as well as the stand-up time (R^2 0.407, OR = 1.7, $p = 0.016$) and the mediolateral sway (R^2 0.217, OR = 1.6, $p = 0.022$). Moreover, including such parameters in a multivariate model, the baseline UPDRS-II item 13 and the stand-up time independently related to the occurrence of new falls ($p < 0.001$).

Discussion

In this study, we performed a post hoc analysis of the data collected in our previous study on a remote patient monitoring program performed through smartphones during the first

Table 1 Parkinson's disease staging and patient demographic general assessment

		Non-fallers ($n = 29$)	Fallers ($n = 4$)	p
Age		66 (58.5–71.75)	53.5 (50.5–60.25)	0.053
Sex (F, %)		7 (24.1%)	1 (25%)	1.000
Disease duration		6 (3–9)	8.5 (6–16.25)	0.107
Last UPDRS-III		21 (14.5–29.5)	25 (16–31.75)	0.561
Last mHY				
	1.5	5 (17.2%)	0	0.198
	2	10 (34.4%)	0	
	2.5	7 (24.1%)	1 (25%)	
	3	6 (20.6%)	2 (50%)	
	4	1 (3.4%)	1 (25%)	
LEDD		600 (422.5–1032.5)	697.5 (285–918.75)	0.890
Baseline UPDRS-II total		11 (7–13)	19 (16.25–24)	*0.005*
Baseline UPDRS-II item 13				
0		25 (86.2%)	0	*0.000*
1		2 (6.9%)	2 (50%)	
2		2 (6.9%)	1 (25%)	
3		0	1 (25%)	

Statistical significance is marked in italic bold

Table 2 Differences across groups in smartphone-derived parameters

	Non-fallers (n = 29)	Fallers (n = 4)	p-value
Stand-up time (s)	1.77 (1.26–1.92)	2.28 (1.87–2.77)	**_0.020_**
Rotation time (s)	1.83 (1.10–1.93)	2.03 (1.67–2.79)	0.167
Sit down time (s)	3.2 (2.64–3.92)	3.2 (2.61–4.29)	0.864
Total time (s)	15.38 (13.21–20.55)	21.58 (15.58–29.81)	0.098
Walking time (s)	3.90 (3.11–6.13)	6.91 (4.37–9.93)	0.068
ML sway (cm)	4.5 (3.3–6.1)	8.15 (6–10.3)	**_0.022_**
Number of steps	7.82 (6.20–9.68)	9.08 (7.40–10.82)	0.332
Step length (cm)	41.8 (33.5–55.5)	42.2 (32–51.5)	0.868
Step period	0.46 (0.34–0.56)	0.50 (0.42–0.69)	0.411
AP step correlation	0.33 (0.24–0.47)	0.35 (0.17–1.46)	0.899
ML step correlation	0.39 (0.20–0.52)	0.17 (0.14–0.33)	0.066
Neutral stance yaw	4.46 (1.34–19.97)	22.29 (3.02–39.49)	0.414
Neutral stance pitch	5.42 (1.68–21.65)	5.95 (1.36–32.28)	0.940
Neutral stance roll	23.74 (2.9–63.50)	30.30 (6.74–85.02)	0.834
PD status	w3 (2.4–4)	3.15 (2.62–3.82)	0.911

Statistical significance is marked in italic bold

COVID-19 lockdown [5]. The 3mTUG was able to differentiate the PD "fallers" by the "non-fallers" over a 4-weeks observation period by two parameters, namely the stand-up time and the mediolateral sway. The smartphone tests were generally acquired by patients reporting a good motor efficiency (PD status score) in both groups — dulling the putative influence of the OFF-medication state. The static balance (yaw, pitch, and roll smartphone motions) was not able to differentiate the PD "fallers" by the "non-fallers" and to correlate to the falling event. Hence, we might confirm — even in our limited sample — that the fall risk assessment in PD should point to the investigation of dynamic more than static balance [1]. The history of falls remains — even in according to our data — the major determinant of new falls, as also acknowledged by previous literature [1]. Nevertheless, the rate of fallers at baseline (i.e., before the lockdown) was higher (8 out of 33, ~24%) if compared to prospective data (~12%). This was probably due to the change of patients' habits during lockdown when people were forced to spend most of their time at home. The "lockdown-fallers" might have experienced a different kind of falls with respect to the pre-lockdown ones — confirming that the fall in PD is the result of a complex interplay of factors. In this regard, data from the 3mTUG are not surprising, since it is conceivable that in a small environment such the patients' house, an impairment of the sit-to-stand body transition (i.e., expressed through stand-up time) might have had a greater impact on falling than other parameters such as stride time variability and walking cadence and pace (i.e., acknowledged predictors) [1].

The sit-to-stand and the stand-to-sit body transitions, collectively named postural transitions (PTs), are essential component of anyone everyday mobility and quality of life. Their correct execution depends on the functionality of highly integrated networks such as the cortico-striatal-pallidum-pedunculopontine circuit which is a main generator of the anticipatory postural adjustments (APAs) and is compromised in the evolving picture of PD [7]. Other factors might influence the process of "rising from a chair" such as vestibular and autonomic functionality, cognitive status, and the age-related overall degeneration of the locomotor system. All the above-mentioned features, together with the loss of reactive postural responses and the variability of the body center of pressure, may show an insufficient response to the dopaminergic replacement therapy — which could in turn favor pathological condition such as orthostatic hypotension or foster falling episodes _di_ per se [1, 8]. Our results on stand-up time and mediolateral sway are in line with the available literature. Indeed, altered sit-to-walk parameters (i.e., PTs and center of pressure variability) have already been associated to falls and other related phenomena such as freezing of gait [9, 10].

Hence, during the social restrictions observed in COVID-19 pandemic, the relation between PTs and falls could have been stricter due to the presence various possible environmental and life-style factors. More specifically, the postural instability had already been pointed out as a cause of indoor more than outdoor falls in prospective studies [11]. The lockdown might have exacerbated this kind of disease-related risk factor and patients who were forced to stay home were possibly more exposed to PT-related falls. Also, the lack of exercise might have had a role in favoring fall episodes. Indeed, physiotherapy and physical activity were not considered among the "essential needs" universally allowed during the 2020 lockdown in Italy. Their beneficial effect on PTs and on the falling risk is well acknowledged nowadays [12, 13] and the discontinuation of physiotherapy was declared as a main factor of a detrimental in PD-related quality of life in a similar cohort from Italy collected during the same timeframe [14].

Postural reflexes and transitions are also crucial for PD clinical evaluation. Indeed, both are listed as pivotal points in the UPDRS ("rising from a chair," quality, and number of attempts) and in the Hoehn and Yahr (i.e., "presence of postural impairment" as a prominent element to establish the transition from the stage 2.5 to the stage 3) [15].

Indeed, the use of clinical rating scales is often influenced by the raters' own variability as well as by a large amount of patient and environmental related contingencies (e.g., outpatient clinic infrastructures, patient emotional status, timing of the clinical assessment with respect to the therapy intake) and would take great advantage by reliable technologies able to provide remote, robust, and reproducible data [3, 5]. A subjective clinical evaluation may be not sensitive enough to estimate subtle PD progression and accurately predict the risk of falling — especially if compared to kinematic analysis, which allows an extensive and

robust evaluation of movement and balance in various experimental settings [1, 3, 5]. For instance, the kinematic analysis predicts the occurrence of falls better than the clinimetric approach even in the presence of an established major determinant of orthostatic unsteadiness such as the autonomic impairment [17].

Hence, the increasing spread of new technologies and the use of integrated sensors may have a dramatic impact on PD tracking, since they allow the assessment of different kinematic parameters in supervised but also unsupervised domestic environment [16]. Moreover, the worldwide spread of smart devices embedded with sensors and apps represents a unique occasion to improve the management of neurological patients, especially in the field of movement disorders.

Our finding contributes to the knowledge about falls in PD and may be of help in establishing an individually tailored fall prevention programs, eventually based on telemedicine. To such extent, the pandemic gave us the opportunity to explore the feasibility and the scientific content of the use of telerehabilitation [6]. The latter should be built around patient needs and enriched by novel digital solutions such as virtual reality and sensor-based kinematic feedback [6, 18, 19].

Main limitations of this study are represented by the small sample size and the short duration of the follow-up, which was due to limited resources during the pandemic. However, we think that the real-life data coming from such a clinical landscape could represent a considerable starting point to improve our knowledge on patient remote monitoring.

Declarations

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