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Is there any relationship between scoliosis, cervical pain and postural imbalance in Parkinson's disease? A cross-sectional pilot study

Gianpaolo Ronconi,[1] Dario Mattia Gatto,[2] Mariantonietta Ariani,[2] Sefora Codazza,[3] Fabio Ingravalle,[4] Giorgio Ferriero,[5,6] Daniele Coraci,[7] Paola E. Ferrara[3]

[1]*Catholic University of the Sacred Heart, Rome, Italy;* [2]*Department of Neurosciences, Sense Organs and Thorax, Catholic University of the Sacred Heart, Rome, Italy;* [3]*University Polyclinic Foundation A. Gemelli IRCCS, Rome, Italy;* [4]*Hospital Health Management Area, Local Health Authority "Roma 6", Albano Laziale, Italy;* [5]*Unit of Physical and Rehabilitation Medicine, Istituti Clinici Scientifici Maugeri IRCCS, Tradate, Varese, Italy;* [6]*Department of Biotechnology and Life Sciences, University of Insubria, Varese, Como, Italy;* [7]*Department of Neuroscience, Section of Rehabilitation, University of Padova, Padua, Italy.*

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Abstract

Parkinson's disease (PD) is defined by progressive worsening of gait, posture, and balance, as well as disability in daily life activities, and improvement in chronic musculoskeletal pain, particularly neck pain associated with worsening of balance. The study's goal is to look into the relationship between scoliosis, balance, and cervical pain in Parkinson's disease patients. Cross-sectional, pilot study. The study included 16 Parkinson's patients. Neck cervical pain was measured using the pain visual analogue scale and the short form McGill pain questionnaire, while dynamic balance was assessed using static balance, Tinetti, Berg Balance, and the Short Physical Performance Battery scales (SPPB). Cobb angles are measured on a whole-spine standard X-ray to assess spinal scoliosis. An observational statistical analysis was performed with patients subdivided into two groups: non-scoliosis (NS) and true scoliosis (TS) based on whether they presented a Cobb's angle below or ≥10°. Neck pain was reported by 37% (n=3) of participants in the NS group versus 50% (n=4) in the TS group. Neck pain was more prevalent in patients with a disease duration of less than 48 months (n=6; 75.0% *vs* n=1; 12.5%; p-value <0.05). Scoliosis, cervical pain, and postural imbalance are all significant but often overlooked Parkinson's disease complaints.

Key Words: Parkinson's disease, scoliosis, postural imbalance, pain.

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Parkinsons's disease (PD) is a chronic neurodegenerative disorder characterized by progressive worsening of gait, posture and balance. Abnormal postures and spinal misalignment tend to reduce dexterity, disrupt gait, and interfere with daily life activities also increasing the susceptibility to musculoskeletal pain or discomfort.[1] This becomes particularly evident in more advanced stages of the disease where striking sagittal or coronal plane spinal deviations occur (*e.g.*, anterocollis, scoliosis, camptocormia and Pisa syndrome) and are further worsened by the process of aging.[2] Behind the origin of these clinical signs some authors suggest several peripheral (*e.g.*, muscle rigidity, myopathy and soft tissue changes) and central causes (*e.g.*, proprioceptive disintegration, dystonia and medication effects). However, the precise mechanism remains unclear.[3] Spinal scoliosis is a common disorder in PD with a reported prevalence between 43% and 90%.[4] Several experiments of artificially induced hemiparkinsonism on animal models have been showing to induce scoliosis, suggesting the possibility that this condition may have a neurologic background in some cases.[1] It is largely known that spinal regions are not independent of one another, and that the alteration of one segment can have repercussion on the other segments.[5] A study of Topalis and colleagues[6] found a higher prevalence of neck pain in adults with idiopathic scoliosis. Shin *et al.*[7] has shown that neck pain is associated with excessive cervical lordosis, upper thoracic kyphosis and altered shoulder and scapular kinematic in young women with forward head posture.[7] In addition to spinal deformities, individuals with chronic pain were shown to display balance impairment in multiple studies.[8,9]

Despite the significant functional and quality of life impact of cervical pain and the vulnerability of these patients to develop spinal deformities and postural instability, so far, very little attention has been paid in the assessment of the relationship between these factors. Therefore, in this study, we aimed to investigate whether a correlation between scoliosis, poor static and dynamic balance, and cervical pain exists in a group of patients affected by PD. To our knowledge no previous study has been published that investigated this kind of relationship.

Materials and Methods

For this pilot, cross-sectional study, 16 consecutive patients with idiopathic PD that presented a scoliotic posture were recruited from the Physical and Rehabilitation outpatient clinic of the Agostino Gemelli University Hospital of Rome between May and October 2022. Part of these patients has been included in our previous study.[10] The present study complies with the STROBE guidelines.

Eligibility criteria

The inclusion criteria were a diagnosis of PD according to the criteria of the Brain Bank of London; Hoehn and Yahr stage II-III; absence of cognitive impairment (MMSE> 24/30); effective pharmacological control of the pathology; acceptance and signature of informed consent.
The exclusion criteria comprised: a diagnosis of atypical Parkinsonism; presence of a clinically diagnosed Pisa syndrome, poor pharmacological compensation of the disease; diagnosis of other neurological, neuromuscular diseases or osteo-articular pathologies; visual impairment or vestibular disorders.

Clinical evaluation

Medical examination

Patients that met the inclusion criteria underwent a medical examination during which anamnestic data were collected regarding the age, weight, height, Body Mass Index (BMI), disease duration and current PD treatment including daily dose of Levodopa. All the patients were examined in the morning during the "ON" pharmacological phase. Cervical pain was assessed during the medical examination by administering both the pain Visual Analogue Scale (VAS) and the McGill pain questionnaire. The patient was classified as having pain if cervical pain was reported in at least in one of the two questionnaires.

Radiographic evaluation

Each patient underwent a standard whole-spine X-ray in two planes (antero-posterior and lateral) in orthostatism. A senior radiologist evaluated the radiological images for the presence of spinal scoliosis and other deformities. To avoid misinterpretation with Pisa syndrome, which is a reversible lateral bending of the trunk, scoliosis was defined as the presence of a radiographic Cobb's angle of at least 10° on the coronal plane, with or without vertebral rotation, that is not corrected by passive movement or supine position.[3] The curve was classified according to the location of its apex (most lateral vertebra) and its extremities (most peripheral upper and lower vertebrae), the direction of the convexity (right or left) and the curvature range (broad or narrow). The presence of other pathological findings in the coronal (*e.g.*, compensation curve) or sagittal plane (*e.g.*, kyphosis, lordosis, listhesis, etc.) was also reported when present.

Stabilometric evaluation

Static balance was assessed through a standardized stabilometric exam performed on a 'Prokin PK 254 P' device produced by TecnoBody Srl. (Dalmine, BG, Italy). The device consists of a static platform (47 cm in circumference) with four piezoelectric sensors positioned at the extremities of the four cardinal points. The temporal resolution was 0.01 seconds, and the sampling frequency was set at 20 Hz. The patients were asked to stand on the platform for 60 seconds in a neutral position with the feet forming a 30-degree angle. The test was carried out 30 seconds with the eyes open and 30 seconds with the eyes closed. All data were analysed using ProKin 36 software to calculate the centre of pressure (CoP) sway on the X (anterior-posterior) and Y (medio-lateral) axes (mm), the CoP velocity on the X (anterior-posterior) and Y (medio-lateral) axes (mm/s), the sway path perimeter (mm), and the area of the ellipse (mm^2). Lower values reflect greater control in maintaining static balance. We considered as primary outcome the reduction of the length of adaptive movements of the following variables: i) SwayAP and SwayML (mm): standard deviation of CoP time series along the anterior-posterior and medio-lateral axes; ii) VelocityAP and VelocityML (mm/s): velocity of oscillations along the anterior-posterior and medio-lateral axes; iii) Perimeter (mm): total length of CoP trajectory; iv) Area (mm^2): area of the 95 % confidence ellipse;[11] v) $Romberg_{Area}$: ratio between the value of the area with the eyes closed and with the eyes open.

Dynamic balance

Dynamic balance was evaluated using the Tinetti, the Berg Balance scale (BBS) and the Short Physical Performance Battery (SPPB): i) the Tinetti scale is a 16-item standardized screening modality for gait and balance disorders in elderly patients and patients with PD. The scoring system ranges from 0 to 28. The higher the score, the lower the risk of falls;[12] ii) the BBS is a 14-item scale used to test patients with balance problems, validated in PD; iii) the score ranges from 0 to 56 and does not include gait assessment. The lower the score, the greater the risk of falling;[13] iv) the SPPB is used to assess functional mobility in elderly patients or individuals affected by neurological diseases. It includes 3 subsets (walking, sit-to-stand and balance). The score ranges from 0 to 12; the lower the score, the lower the functional ability.[14]
The study was carried out according to the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Policlinico Gemelli Foundation (UCSC prot. N 5492/14, 05.03.2014). All patients provided their informed consent prior to inclusion in the study.

Statistical analysis

Per-protocol analysis was carried on. Statistical analyses were performed using Statistic Package for Social Sciences

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(SPSS) version 25.0. Data for categorial variables were expressed as absolute numbers and percentage and the Fisher exact or X^2 tests were used to compare them. Continuous variables were expressed as mean, standard deviation (SD) and minimum and maximum value. Due to the small sample size, it was assumed a priori that the distribution of the continuous variables was non-normal. For this reason the Mann-Whitney test was used to compare the variables examined between the two groups. Linear univariate and multivariate and logistic regression model analysis were performed to provide an adjusted assessment of factors potentially associated with the presence of scoliosis in patients with PD.

Results

A total of 16 patients affected by PD were assessed for presence of scoliosis (8 males and 8 females). Half of them met the criteria for scoliosis3 and were classified as the "true scoliosis" group (TS); the other half presented a Cobb's angle of less than 10° and were defined as the "non-scoliosis" group (NS). Table 1 summarizes the clinical and demographic characteristics of the patients. Detailed clinical presentation and demographic differences at enrollment between men and women are presented in the Appendix (Table 1). The average age of men 76.75 ± 4.29 was higher than women 64.13 ± 9.82 (p-value < 0.05).
The NS group presented a thoracic spinal deviation below the cutoff angle for diagnosing scoliosis. In one case we found a significant dorsal kyphosis (55°) and in another case a grade I retrolisthesis of T2 over L2. In the TS group, except for one patient who presented a severe scoliosis (50.15°), all the other patients presented a mild form scoliosis with a Cobb's angle ≤ 20°. In most cases the curvature was lumbar and broad range. Other spinal abnormalities observed included one case of listhesis and two cases of vertebral fracture. Details about the radiological characteristics of the patients are displayed. Frequency of neck pain revealed a prevalence of 37.5% (n=3) in the NS group compared to 50% (n=4) in the TS group, however it was not possible to reject the null hypothesis. Also, any difference in cervical pain severity was observed between groups in both the VAS and in the McGill scores (Table 1).
Subgroup analysis showed that subjects with a disease duration less than 48 months had a higher prevalence of neck pain compared to those with a disease duration longer than 48 months (n=6; 75.0% *vs* n= 1; 12.5%; P-value <0.05). Static balance evaluation difference between the TS group and the NS group are shown in the upper part of Table 2. Likewise, dynamic balance evaluation difference between the TS group and the NS group are shown in the lower part of Table 2. Detailed differences regarding the clinical assessment of static and dynamic balance between men and women are shown in the Appendix (Table 2A).
Linear regression models did not show any worthy of at-

Table 1. *Clinical and demographic characteristics of the patients and evaluation of cervical pain according scoliosis classification.*

	Non-Scoliosis (N=8; 50%) Mean±SD (min - max)	**True Scoliosis (N=8; 50%) Mean±SD (min - max)**	**P value**
Sex (male/female)	6 (75%) / 2 (25%)	2 (25%) / 6 (75%)	0.13[a]
Age (years)	70.63±10.20 (55–82)	70.25±10.87 (53–81)	0.964[b]
BMI (kg/m²)	26.00±2.90 (23–31)	25.16±3.75 (21–32)	0.50[b]
Length of disease (months)	66.00±32.14 (20–112)	76.00±75.26 (28–232)	0.69[b]
UPDRS score	20.25±6.20 (9–28)	24.43±13.39 (9–44)	0.61[b]
H & Y classification	1.69±0.26 (1.50–2.00)	1.929±0.70 (1.50–3.00)	0.61[b]
LEDD (mg/day)	456.25±247.04 (100–800)	450.00±386.22 (0–1000)	0.87[b]
Number of drugs	2.38±1.06 (1–4)	2.14±1.06 (1–4)	0.35[b]
$VAS_{cervical}$	2.50±3.50 (0–8)	3.75±4.02 (0–8)	0.50[b]
$McGill_{cervical}$	6.88±9.70 (0–21)	8.88±10.43 (0–26)	0.80[b]
Reported pain/non-reported pain	3 (37.5%) / 5 (62.5%)	4 (50%) / 4 (50%)	0.99[a]

BMI, Body Mass Index; UPDRS, Unified Parkinson's Disease Rating Scale; LEDD, Levodopa Equivalent Daily Dose.
[a]Fischer Test; [b]Mann-Whitney Test.

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tention association between the Cobb's angle and the SPPB total, Tinetti scale, BBS or other stabilometric parameters (Table 3). Detailed graphic representa-tion of the distribution of the studied models relating to the Cobb's angle are present in the appendix via scatterplot (Figure 1).
Patients with scoliosis showed a lower variability of the perimeter but a higher variability of the area at the Romberg index compared to the SA group.
Also, linear regression models showed no association between cervical pain (respec-tively VAS score and Mc Gill score) and the SPPB total, Tinetti scale, BBS or other stabilometric parameters (Table 4). Detailed graphic representation of the distribution of the studied models relating to VAS score and Mc Gill score are present in the appendix via scatterplot (respectively Figure 2 and 3).
Furthermore, patients with neck pain showed a lower variability of the Romberg index (both area and perimeter) than patients without neck pain.

Table 2. *Clinical evaluation of static and dynamic balance according scoliosis classification.*

	Non-Scoliosis (N=8) Mean±SD (min - max)	True Scoliosis (N=8) Mean±SD (min - max)	P value
SPPB $_{Equilibrium}$	3.13±0.64 (2–4)	3.00±1.00 (2–4)	0.87[b]
SPPB $_{Gait}$	4.00±0.00 (4–4)	3.43±0.78 (2–4)	0.19[b]
SPPB $_{Sit-to-stand}$	3.13±0.64 (2–4)	2.43±1.51 (0–4)	0.46[b]
SPPB $_{Total}$	10.25±1.03 (9–12)	8.86±3.02 (5–12)	0.53[b]
Tinetti	24.13±1.12 (22–26)	21.14±4.18 (12–24)	0.03[b]
BBS	47.00±1.60 (45–50)	45.29±5.09 (37–52)	0.46[b]
Eyes open			
Sway AP (mm)	3.13±1.24 (1–4)	3.50±1.60 (2–6)	0.99[b]
Sway ML (mm)	2.38±1.50 (1–6)	3.00±1.77 (1–7)	0.19[b]
Velocity AP (mm/s)	9.25±5.82 (3–18)	7.38±2.82 (4–13)	0.72[b]
Velocity ML (mm/s)	5.25±1.75 (3–7)	4.87±1.53 (3–7)	0.72[b]
Perimeter (mm)	279.88±143.61 (114–496)	237.50±74.91 (158–387)	0.72[b]
Area (mm^2)	145.75±108.42 (32–383)	183.25±150.85 (59–490)	0.50[b]
Eyes closed			
Sway AP (mm)	5.25±2.60 (1–10)	5.50±1.69 (4–8)	0.96[b]
Sway ML (mm)	3.25±1.83 (2–7)	3.38±1.68 (1–6)	0.80[b]
Velocity AP (mm/s)	26.25±28.68 (5–94)	17.38±10.48 (7–37)	0.72[b]
Velocity ML (mm/s)	9.62±7.02 (4–26)	9.13±4.97 (4–20)	0.96[b]
Perimeter (mm)	705.38±723.49 (153–2411)	509.50±287.25 (196–963)	0.88[b]
Area (mm^2)	393.88±433.23 (44–1400)	334.75±194.49 (81–580)	0.88b[b]
Romberg $_{(EC/EO)}$			
Perimeter (mm)	2.25±1.24 (1.34–4.97)	2.05±0.83 (1.21–3.93)	0.64[b]
Area (mm^2)	2.75±2.75 (1.34–9.52)	2.24±1.44 (1.01–5.34)	0.78[b]

[b]*T-student test.*

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Table 3. *Association between Cobb's angle and the Tinetti scale, SPPB, BBS or other stabilometric parameters.*

Cobb's angle	Univariate Models[1] Unstandardized B coefficients	P-Value	R Square[a]	Multivariate Models[2] Unstandardized B coefficients	P-Value	R Square[b]
$SPPB_{Total}$	-0.39±1.69	0.82	0.01	-0.51±2.21	0.82	0.56
Tinetti	-0.49±1.16	0.68	0.02	0.17±3.15	0.96	0.52
BBS	-0.79±0.94	0.42	0.05	-0.03±1.10	0.98	0.55
$Perimeter_{(EC/EO)}$	4.68±2.93	0.13	0.15	4.84±2.97	0.15	0.69
$Area_{(EC/EO)}$	1.55±1.47	0.31	0.07	1.27±1.68	0.48	0.59

[1]Unadjusted model; [2]Adjusted model for age, sex, disease duration, BMI; LEDD (mg/day) and VAS score; [a]R Square for univariate models; [b]R Square for multivariate models.

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Table 4. *Association between cervical pain and the Tinetti scale, SPPB, Berg balance or other stabilometric parameters.*

VAS score	Univariate Models Unstandardized B coefficients	P-Value	R Square	Multivariate Models Unstandardized B coefficients	P-Value	R Square
$SPPB_{Total}$	0.36±0.43	0.43	0.05	0.62±0.44	0.29	0.904
Tinetti	0.25±0.29	0.41	0.05	1.05±0.72	0.28	0.908
Berg Balance	0.15±0.27	0.59	0.02	0.36±0.28	0.33	0.895
$Perimeter_{(EC/EO)}$	-1.08±0.92	0.26	0.09	-1.88 ±0.60	0.88	0.968
$Area_{(EC/EO)}$	-0.49±0.44	0.28	0.08	-0.59±0.29	0.17	0.939
Mc Gill score	**Univariate Models Unstandardized B coefficients**	**P-Value**	**R Square**	**Multivariate Models Unstandardized B coefficients**	**P-Value**	**R Square**
$SPPB_{Total}$	1.11±1.22	0.38	0.060	1.36±1.41	0.44	0.888
Tinetti	0.72±0.84	0.41	0.053	2.27±2.32	0.43	0.890
Berg Balance	0.48±0.76	0.54	0.029	0.72±0.91	0.51	0.876
$Perimeter_{(EC/EO)}$	-2.78±2.43	0.27	0.086	-5.26±1.41	0.06	0.980
$Area^{(EC/EO)}$	-1.31±1.17	0.28	0.082	-1.77±0.62	0.10	0.968

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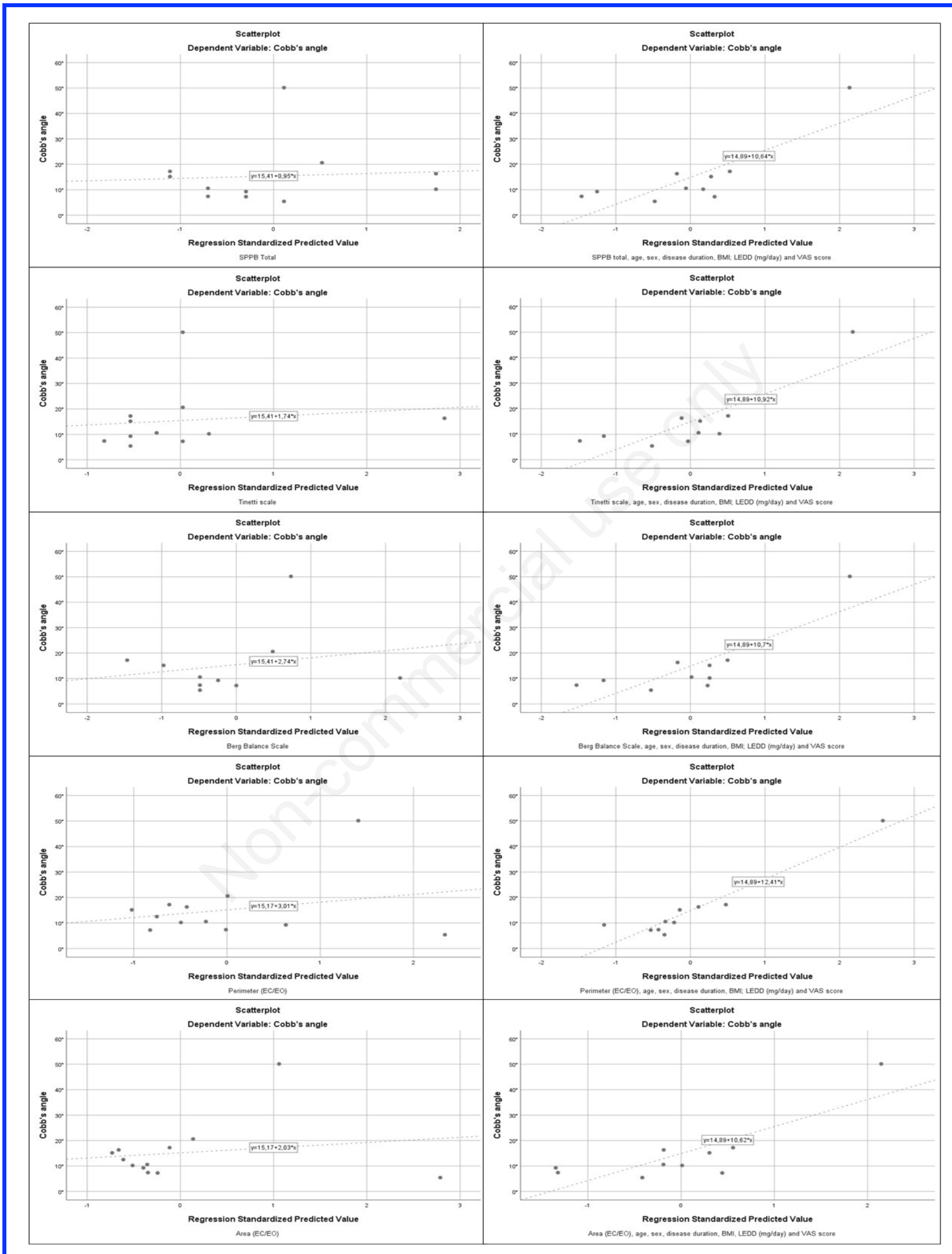

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Figure 1. *Scatter plots of association between Cobb's angle and the SPPB total, Tinetti scale, BBS or other stabilometric parameters, univariate (left) and multivariate models (right).*

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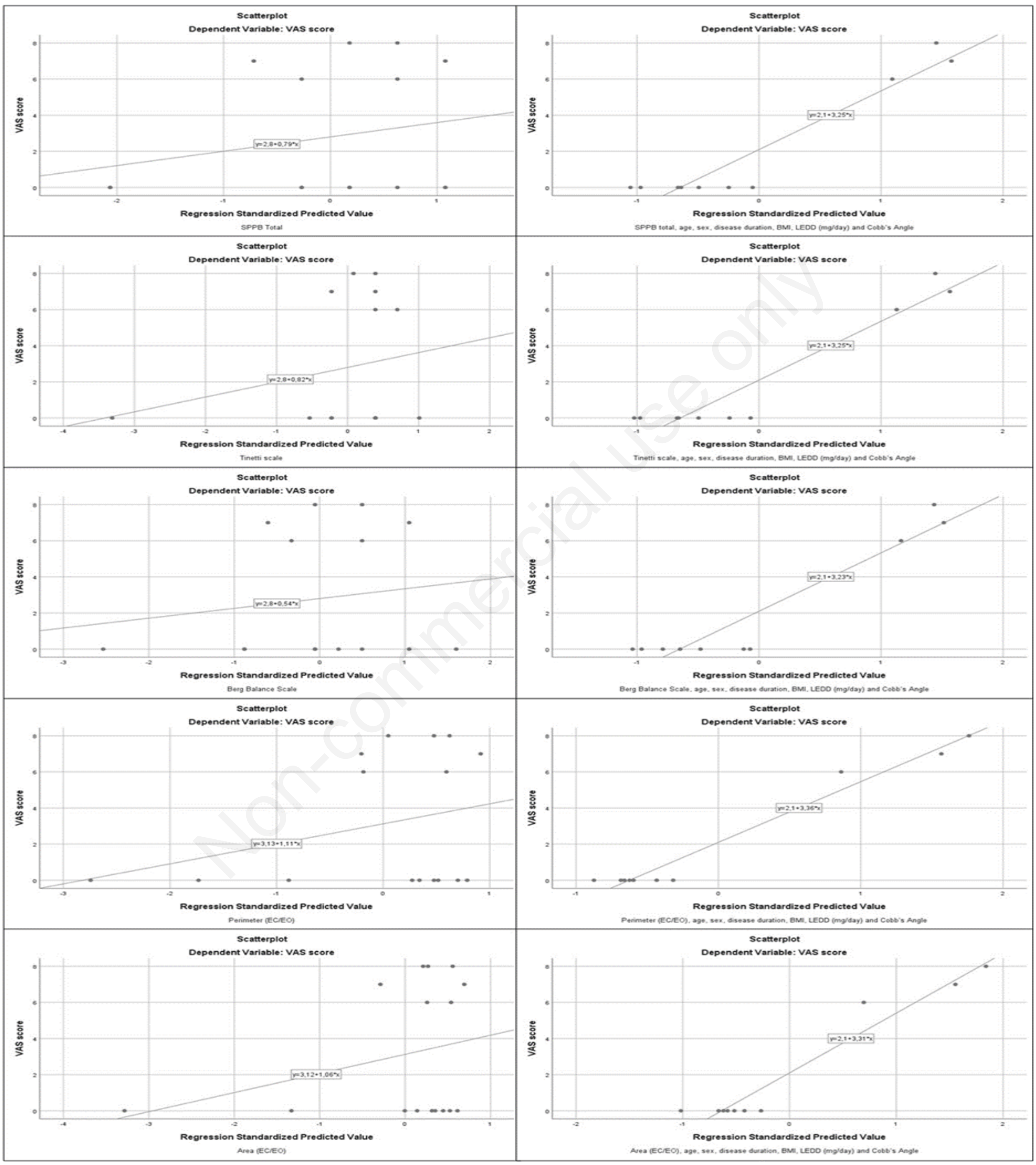

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Figure 2. *Scatter plots of association between VAS score and the SPPB total, Tinetti scale, BBS or other stabilometric parameters, univariate (left) and multivariate models (right).*

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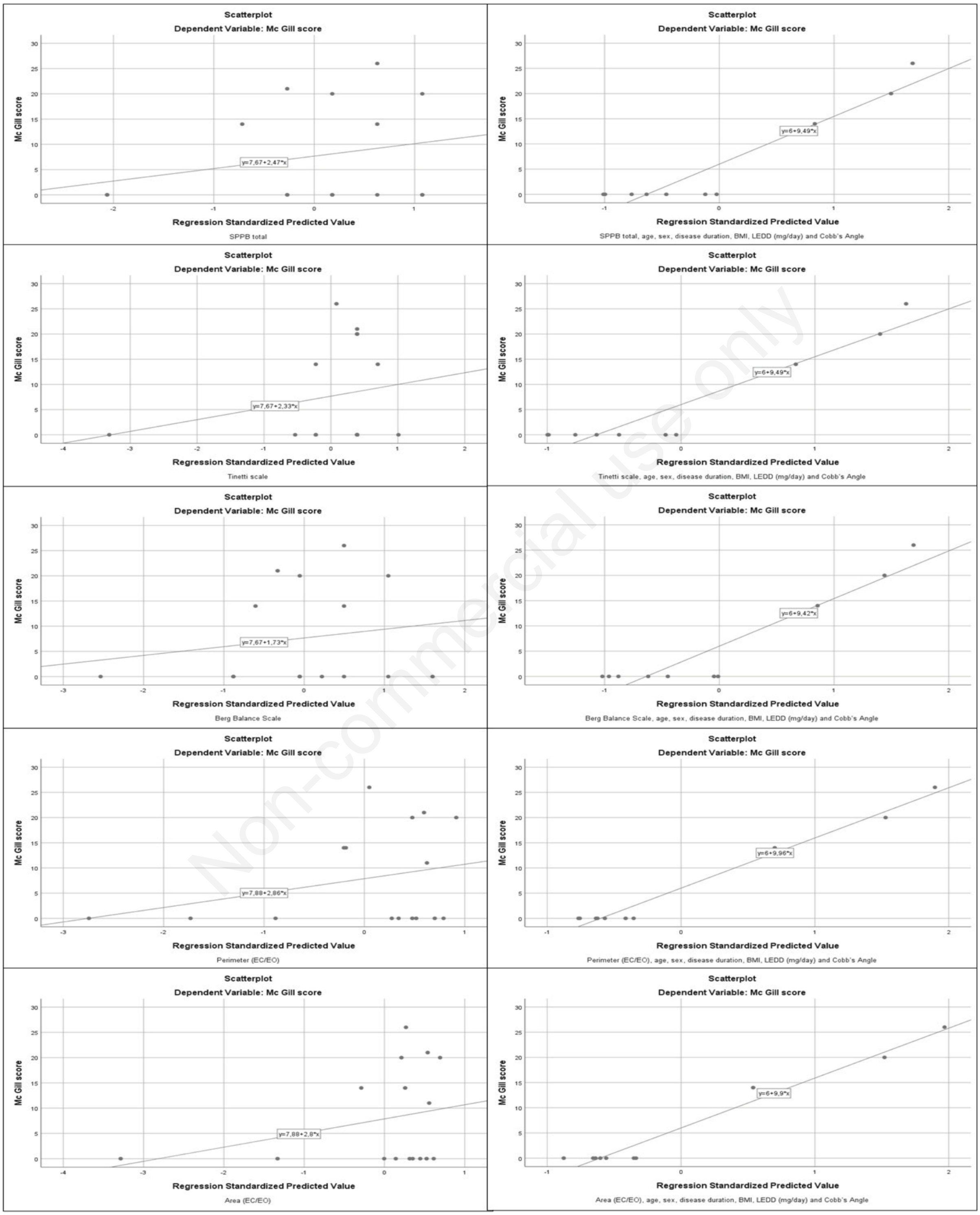

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Figure 3. *Scatter plots of association between MC Gill score and the SPPB total, Tinetti scale, BBS or other stabilometric parameters, univariate (left) and multivariate models (right).*

Discussion

Postural deformities including scoliosis tend to occur more often in PD than in the general elderly population.[2,15] Scoliosis and abnormal posture can produce any type of joint pain and exacerbate the overall sensory impairment and the risk of falls in PD.[15] Static and dynamic balance normally rely on the sound integration of visual, vestibular, and proprioceptive sensory information within the basal ganglia and on a coordinated reflex and motor activity.[16] Many studies have demonstrated that patients with PD have subnormal integration of peripheral sensory stimuli with greater reliance on the visual input during static and dynamic motor tasks.[3,16] Furthermore, the development of balance problems and falls is typically indicative of disease progression and worse prognosis.[17] In our study, static and dynamic balance evaluation did not reveal any important differences between the TS and the NS group.

The regression models highlighted that the demographic and clinical characteristics of the patients can significantly influence the dynamic balance assessment questionnaires, but this evidence does not translate into worse stabilometric data in those who had a greater Cobb angle. This could indicate that scoliosis, neck pain and postural imbalance do not have a linear association between them. The severity of PD and the severity of scoliosis are able to influence dynamic imbalance and risk of falling, but this association still needs to be further studied to identify whether the two conditions together determine an increased risk compared to these two risk factors considered individually.

The literature does not provide any data regarding a possible correlation between scoliosis and balance problems in PD so that the only comparison can be done with individuals with idiopathic scoliosis and no PD. In this regard, previous studies have shown a significant correlation between scoliosis and static imbalance in adolescents with moderate idiopathic scoliosis compared to the healthy controls.[18,19] Furthermore, patients with high major curves had a better postural stability than those with low major curves.[20] Regarding the correlation between scoliosis and dynamic imbalance, compared to healthy controls, Shirado *et al.*[21] found a significant lower weight's shift in the patients with idiopathic scoliosis during both slow and fast side-shifts. Furthermore, weight's shift was less on the concave side than on the convex one. Another study by Haber *et al.*[22] suggests that scoliotic subjects have a slower speed of gait due to a shorter stride length and a longer stride time. Moreover, they display variations in the timing of muscle activation. Also in this case, to the best of our knowledge, no study investigated the correlation between scoliosis and walking problems in PD. This correlation should be further explored in future studies.

Literature data on neck pain prevalence are currently insufficient both in PD patients and in individuals with idiopathic scoliosis. The study of Kim *et al.*[23] is the only one reporting a prevalence of neck pain of 5.5% in a cohort of 400 patients with PD, while the study of Topalis *et al.*[6] is the only one reporting a prevalence of cervical pain of 42% in adults with idiopathic scoliosis. In our study the prevalence of cervical pain was of 50% in PD patients with scoliosis and 37% in those without scoliosis. Regarding the severity of cervical pain, the average VAS and McGill score was tendentially higher in the TS group compared to the NS group. However, this data did not reach a statistical significance. In contrast, subgroup analysis stratified by disease duration showed that individuals with a disease duration >48 months seem to experience less cervical pain compared to patients with more recent onset of the disease. This data is in contrast with the study of Silverdale *et al.*[24] in which disease duration was not found to influence pain severity in a cohort of 1957 participants with early/moderate PD. Regarding the correlation between neck pain and balance problems, subjects with neck pain did not reveal any difference in dynamic and static balance parameters compared to those without it. Like for scoliosis and neck pain, also in this case we did not find any literature data that investigated this kind of relationship in PD patients. However, if we look at the general population, a study of Ruhe *et al.*[8] suggests that individuals with neck pain display diminished proprioception and impaired postural control.

Limitations of the study

This study has a few limitations that should be noted. First, the small sample size and the lack of a control group without PD limit the power of our observation. Second, we performed the clinical assessment at the "ON" phase which could have masked the real level of functional disability and pain of the patients. Third, we did not assess the duration of cervical pain in the group of patients who reported it which could have been useful to make further correlations with balance impairment.

Conclusions

Scoliosis, cervical pain and postural imbalance are significant yet often overlooked complaints of PD. Early detection and accurate screening could minimize potential pain and suffering and increase the quality of life. Our results did not show a clear association between scoliosis, cervical pain, and static and dynamic imbalance in PD. However, patients with a disease duration of less than 48 months appear to show a greater frequency of cervical pain. Given the limitations of our study and the paucity of the literature on this subject, further studies are needed to clarify these preliminary findings.

List of abbreviations

PD, Parkinsons's disease
NS, non-scoliosis
TS, true scoliosis
BMI, Body Mass Index
BBS,Berg Balance scale
VAS, Visual Analogue Scale
CoP, centre of pressure
SPPB, Short Physical Performance Battery
SPSS, Statistic Package for Social Sciences
SD, standard deviation
UPDRS, Unified Parkinson's Disease Rating Scale
LEDD, Levodopa Equivalent Daily Dose

Conflict of interest

The authors declare no potential conflict of interest, and all authors confirm accuracy.

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Ethics approval and consent to participate

The study was carried out according to the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Policlinico Gemelli Foun-dation (UCSC prot. N 5492/14, 05.03.2014). All patients provided written informed consent prior to inclusion in the study.

Consent for publication

All patients provided written informed consent for publication prior to inclusion in the study.

Availability of data and materials

Not applicable

Correspondence

Mariantonietta Ariani, Department of Neurosciences, Sense Organs and Thorax, Catholic University of the Sacred Heart, 00168, Rome, Italy.
ORICD ID: 0009-0001-3061-3575
E-mail: mariantonietta.ariani01@icatt.it

Gianpaolo Ronconi
ORICD ID: 0000-0002-7310-093X
E-mail: gianpaolo.ronconi@policlinicogemelli.it

Dario M. Gatto
ORICD ID: 0000-0002-9664-0779
E-mail: dario.gatto90@gmail.com

Sefora Codazza
ORICD ID:0009-0004-0282-2822
E-mail: sefora.codazza@guest.policlinicogemelli.it

Fabio Ingravalle
ORICD ID: 0000-0001-6295-9848
E-mail: fabio.ingravalle@gmail.com

Giorgio Ferriero
ORICD ID: 0000-0002-7873-6777
E-mail: giorgio.ferriero@icsmaugeri.it

Daniele Coraci
ORICD ID: 0000-0002-7019-9006
E-mail: danielecoraci@aol.com

Paola E. Ferrara
ORICD ID : 0000-0002-1903-3449
E-mail: paolaemilia.ferrara@policlinicogemelli.it

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