

Case Reports

Analysis of patellar reflex in Parkinson disease patients after an acupuncture treatment protocol – Case series study



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ABSTRACT

Introduction: The investigation of rigidity physiology in Parkinson's Disease involves the examination of reflexes. Parkinsonian patients often demonstrate reduced sensitivity in polysynaptic reflexes within the leg extensor muscles, which is correlated with their postural instability. The compensatory mechanisms for impaired proprioceptive reflex function may involve alterations in intrinsic muscle stiffness. The interplay between gait and reflexes is intricately linked to the nervous system's functioning and motor control. Certain reflexes, such as patellar reflex, play a pivotal role in maintaining walking and posture. Ensuring the integrity of these reflexes is essential for facilitating smooth and efficient walking.

Aim: To analyze the behavior of patellar reflex in four Parkinson's Disease patients undergoing an acupuncture treatment protocol.

Methods: This study adopts a case series design. Reflex outcomes based on amplitude and velocity were assessed at six different time moments throughout a month-long treatment protocol using the MP 36, Biopac Systems.

Results: Over the long term, a tendency for an improvement in range of movement and velocity of the patellar reflex, was observed. Nevertheless, in specific cases, a reduction in the amplitude during acute effects was also found.

Conclusion: Our findings suggest that the acupuncture protocol used may lead to a cumulative improvement in efficacy of patellar reflex in patients with Parkinson's disease. However, further in-depth research, including a statistical evaluation with a larger participant pool, is necessary to validate and confirm these promising preliminary results.

1. Introduction and Background

Parkinson's Disease (PD) is a progressive neurodegenerative condition [1]. The rising levels of disability associated with it severely impact the quality of life, leading to elevated rates of institutionalization and subsequently increased healthcare costs [2–4]. Rest tremor, bradykinesia, rigidity, and loss of postural reflexes are commonly recognized as the cardinal signs of PD. Additionally, abnormal motor coordination and

posture, and gait changes are also frequently observed [5].

The exploration of rigidity physiology in PD involves studying reflexes [6]. PD patients display minimal activity of monosynaptic reflexes and diminished sensitivity in polysynaptic reflexes within the leg extensor muscles, which correlates with their postural instability. To some extent, the impairment of proprioceptive reflex function may be offset by alterations in intrinsic muscle stiffness [7].

The connection between gait and reflexes is intricately linked to the

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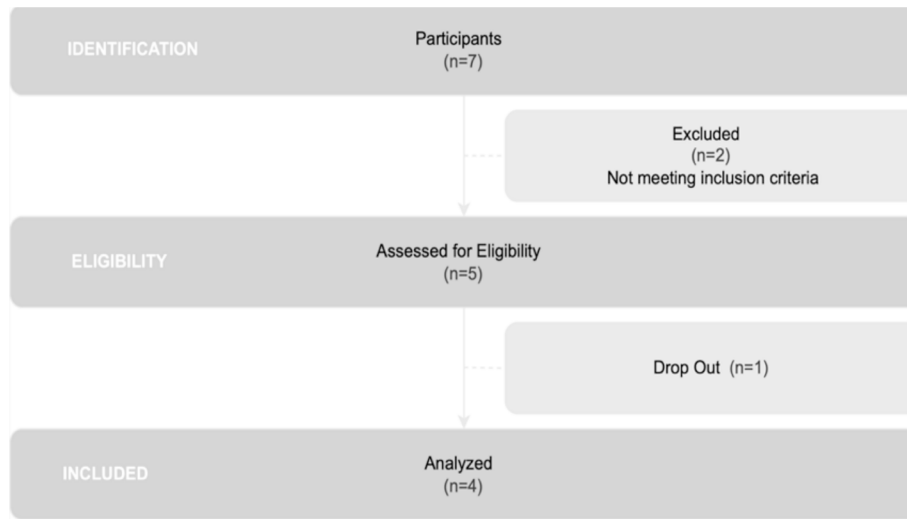


Fig. 1. Flowchart of participants selection.



Fig. 2. Biopac Goniometer.

proper functioning of the nervous system and motor control. Walking requires the coordination of diverse muscle groups, a sense of balance, and reflex responses to uphold stability and ensure proper body movement. Reflexes, particularly the Achilles and patellar reflexes, play a pivotal role in walking and posture. The preservation of these reflexes is indispensable for facilitating a seamless and efficient walking experience [8]. Prior research established that individuals with PD often exhibit abnormal and 'inflexible' postural reflexes. This condition is linked to delayed corrective movements around the ankle joint and an augmented degree of body sway. The heightened muscle stiffness and inflexibility observed in postural reflexes among Parkinson's patients may contribute significantly to impairments in balance during daily activities [9].

Numerous pharmacological and surgical treatments have been devised to address the dysfunctions resulting from PD. Unfortunately, these approaches often come with various side effects. As a result, there is currently no treatment that proves to be entirely efficient in managing

the dysfunctions stemming from the pathology [10]. Given these inadequacies of conventional treatments, many patients are turning to complementary medicine, specifically acupuncture [11]. Several studies demonstrated a correlation between acupuncture and a reduction in motor symptoms in PD [12], as well as improvements in non-motor symptoms including mood, sleep, depression, anxiety, and autonomic dysfunctions [13,14]. Acupuncture has also been associated with combating oxidative stress, reducing inflammatory response, and enhancing the overall quality of life for PD patients [15]. Also, the combination of conventional pharmacological treatment with acupuncture significantly enhances motor function [16,17]. These effects of acupuncture demonstrate similarities to neuromodulation in managing inflammation and brain functional connectivity (BFC). In this sense, potential acupuncture mechanisms include, but are not limited to activating the anti-inflammatory pathway through vagal stimulation and enhancing brain functional connectivity. So, acupuncture introduces novel treatment possibilities for PD patients, offering personalized neuromodulatory therapies [18].

Currently, there is limited body of evidence about the possible effect of acupuncture in reflex behavior in PD patients. Through this preliminary study, our goal is to gain insights into potential alterations in the range of movement of patellar reflex because of an acupuncture protocol treatment in patients with PD. Additionally, we aim to explore whether the obtained results are significant enough to warrant further

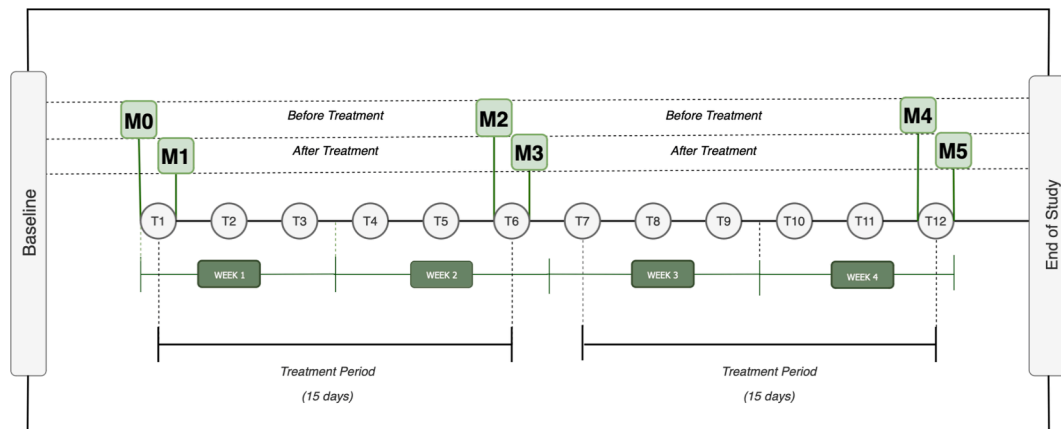


Fig. 3. Design Study

Legend: M0 = Moment zero; M1 = Moment one; M2 = Moment two; M3 = Moment three; M4 = Moment four; M5 = Moment five; T1 = Treatment one (...) T12 = Treatment 12.

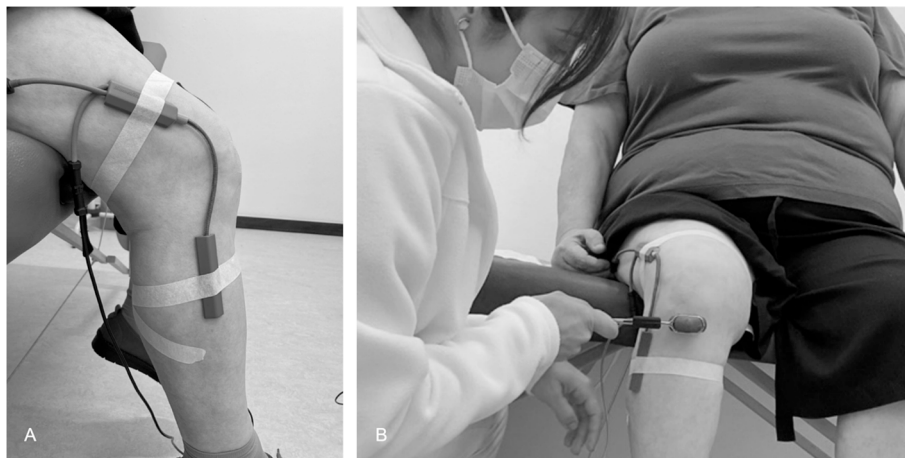


Fig. 4. Procedure of the patellar reflex. A – Lateral side of goniometer application; B – Front side of patellar stimulation.

Table 1
Sample characterization.

Patients	Variables				
	Age	Gender	Disease degree	affected side	Major symptoms
ID 01	72	Female	4	Right	Gait and balance
ID 02	63	Male	3	Left	Muscular Stiffness
ID 03	48	Male	2	Right	Muscular Stiffness and Gait and Balance
ID 04	48	Male	1	Right	Tremor

in-depth analysis. The patients of the study were treated in a clinical evaluation context and the respective results were reported as case studies.

2. Material and Methods

This research comprises a case series study wherein we conducted an in-depth examination of four Parkinson’s disease patients to garner detailed insights into the changes in the Patellar reflex following an acupuncture protocol [19]. The project received approval from the Ethics Committee of the Abel Salazar Institute of Biomedical Sciences at the University of Porto (reference no GS/HCC/9). Additionally, data collection was authorized by the CHUDSA/ICBAS committee, which approved the treatment of personal data in accordance with the law.

Table 2.1
Result of the range of the movement and time for the right and left patellar reflex in each patient.

Patients		Outcomes					
		Right Patellar (RP)			Left Patellar (LP)		
		Amplitude (degrees)	Time (seconds)	Velocity (°/s)	Amplitude (degrees)	Time (seconds)	Velocity (°/s)
Patient 1	M0	4,76	0,55	8,65	*	*	*
	M1	2,36	0,54	4,37	*	*	*
	M2	4,78	0,62	7,71	*	*	*
	M3	3,59	0,73	4,92	*	*	*
	M4	5,34	0,64	8,34	*	*	*
Patient 2	M0	2,46	0,62	3,97	*	*	*
	M1	1,40	0,69	2,03	2,19	0,73	3,00
	M2	33,76	0,26	129,85	151,43	0,52	291,21
	M3	4,88	0,17	28,71	21,11	0,16	131,94
	M4	5,99	0,78	7,68	4,11	0,18	22,83
Patient 3	M4	18,18	0,66	27,55	8,79	0,34	25,85
	M5	5,46	0,61	8,95	2,15	0,66	3,26
	M0	1,16	0,75	1,55	2,47	0,90	2,74
	M1	0,72	0,78	0,92	0,64	0,13	4,92
	M2	2,23	0,66	3,38	3,89	0,74	5,26
Patient 4	M3	1,03	0,57	1,81	2,32	0,63	3,68
	M4	5,48	0,96	5,71	1,87	0,52	3,60
	M5	1,27	0,62	2,05	1,32	0,57	2,32
	M0	5,20	0,92	5,65	5,60	0,61	9,18
	M1	2,46	0,55	4,47	24,34	0,93	26,17
Patient 4	M2	2,23	0,76	2,93	9,65	0,94	10,22
	M3	6,66	0,25	26,64	539,74	0,88	613,34
	M4	*	*	*	*	*	*
	M5	*	*	*	*	*	*

RP = Right Patellar; LP = Left Patellar. *: Evaluation was not possible.

Table 2.2
Result of the Part III of MDS-UPDRS in each patient.

Part III of MDS-UPDRS	PT1		PT2		PT3		PT4	
	M0	M5	M0	M5	M0	M5	M0	M5
3.1 Speech	4	3	3	2	1	1	1	0
3.2 Facial expression	4	3	3	2	2	1	1	0
3.3a Rigidity– Neck	4	3	4	3	3	2	0	0
3.3b Rigidity– RUE	4	3	3	2	3	1	2	0
3.3c Rigidity– LUE	3	2	4	3	2	1	0	0
3.3d Rigidity– RLE	4	3	2	1	3	1	2	0
3.3e Rigidity– LLE	3	2	3	2	2	1	0	0
3.4a Finger tapping– Right hand	4	3	2	1	2	1	1	0
3.4b Finger tapping– Left hand	3	2	3	2	1	0	0	0
3.5a Hand movements– Right hand	4	3	2	1	2	1	1	0
3.5b Hand movements– Left hand	3	2	3	2	1	0	0	0
3.6a Pronation-supination movements– Right hand	3	2	2	1	2	1	1	0
3.6b Pronation-supination movements– Left hand	2	1	2	1	1	0	0	0
3.4b Finger tapping– Left hand	3	2	3	2	1	0	0	0
3.5a Hand movements– Right hand	4	3	2	2	2	1	1	0
3.5b Hand movements– Left hand	3	2	3	2	1	0	0	0
3.6a Pronation-supination movements– Right hand	3	2	1	0	2	1	1	0
3.6b Pronation-supination movements– Left hand	2	1	2	1	1	0	0	0
3.7a Toe tapping– Right foot	3	2	2	1	1	0	1	0
3.7b Toe tapping– Left foot	2	1	3	2	1	0	0	0
3.8a Leg agility– Right leg	3	2	1	0	2	0	1	0
3.8b Leg agility– Left leg	2	2	2	1	1	0	0	0
3.9 Arising from chair	4	3	3	2	1	0	0	0
3.10 Gait	4	2	2	1	4	2	2	0
3.11 Freezing of gait	3	2	2	1	0	0	0	0
3.12 Postural stability	3	2	3	2	4	2	0	0
3.13 Posture	4	3	2	1	3	1	1	0
3.14 Global spontaneity of movement	4	3	3	2	1	0	0	0

Table 2.2 (continued)

Part III of MDS-UPDRS	PT1		PT2		PT3		PT4	
	M0	M5	M0	M5	M0	M5	M0	M5
3.15a Postural tremor– Right hand	2	1	2	1	0	0	4	2
3.15b Postural tremor– Left hand	0	0	3	2	0	0	2	1
3.16a Kinetic tremor– Right hand	1	1	2	1	0	0	3	1
3.16b Kinetic tremor– Left hand	1	1	3	2	0	0	1	0
3.17a Rest tremor amplitude– RUE	1	1	1	0	0	0	2	1
3.17b Rest tremor amplitude– LUE	1	1	2	1	0	0	1	0
3.17c Rest tremor amplitude– RLE	1	1	1	0	0	0	2	1
3.17d Rest tremor amplitude– LLE	1	1	2	1	0	0	1	0
3.17e Rest tremor amplitude– Lip/jaw	0	0	1	1	0	0	1	0
3.18 Constancy of rest tremor	1	1	1	1	0	0	3	1
Total	101/132	71/132	88/132	53/132	50/132	18/132	36/132	7/132
Increase – in points	30	35	32	32	32	29	29	29
Increase – in %	22,7 %	26,5%	24,2%	21,97 %				

All collected data were obtained while prioritizing the privacy of participants, and they were handled confidentially, maintaining anonymity to ensure the protection of all data.

2.1. Participants

All individuals listed in the database of the Associação Portuguesa de Doentes de Parkinson were invited to participate in this study. Subsequently, 7 individuals expressed their consent and completed a questionnaire (n=7). Upon applying the inclusion and exclusion criteria, 5 patients met the criteria for inclusion in this study (n=5). However, one patient was unable to undergo the final evaluation procedure, resulting in a dropout. Therefore, a final sample of 4 individuals (n=4) was considered, as illustrated in Fig. 1.

To be included in the study, subjects had to have a medical diagnosis of PD from a neurologist based on Diagnosis Criteria, evaluated by a clinician [20,21], present stage I-IV on the Hoehn and Yahr Scale [22], a diagnosis of the shaoyin stage, according to the Heidelberg model of TCM, be medically stable for at least 3 months, be acupuncture-naive, and present a duly completed Informed Consent [23].

To minimize potential bias, we excluded individuals with needlestick phobia [24], the presence of dermal lesions at the treatment site, pregnancy or lactation, malignant tumors, bleeding disorders or coagulation problems (anticoagulant therapy) [24], psychiatric disorders [25], cognitive diseases preventing the subject from understanding instructions and neuro-musculoskeletal modifications that would compromise the experimental procedures [26].

We excluded patients with other neurological problems (besides PD)

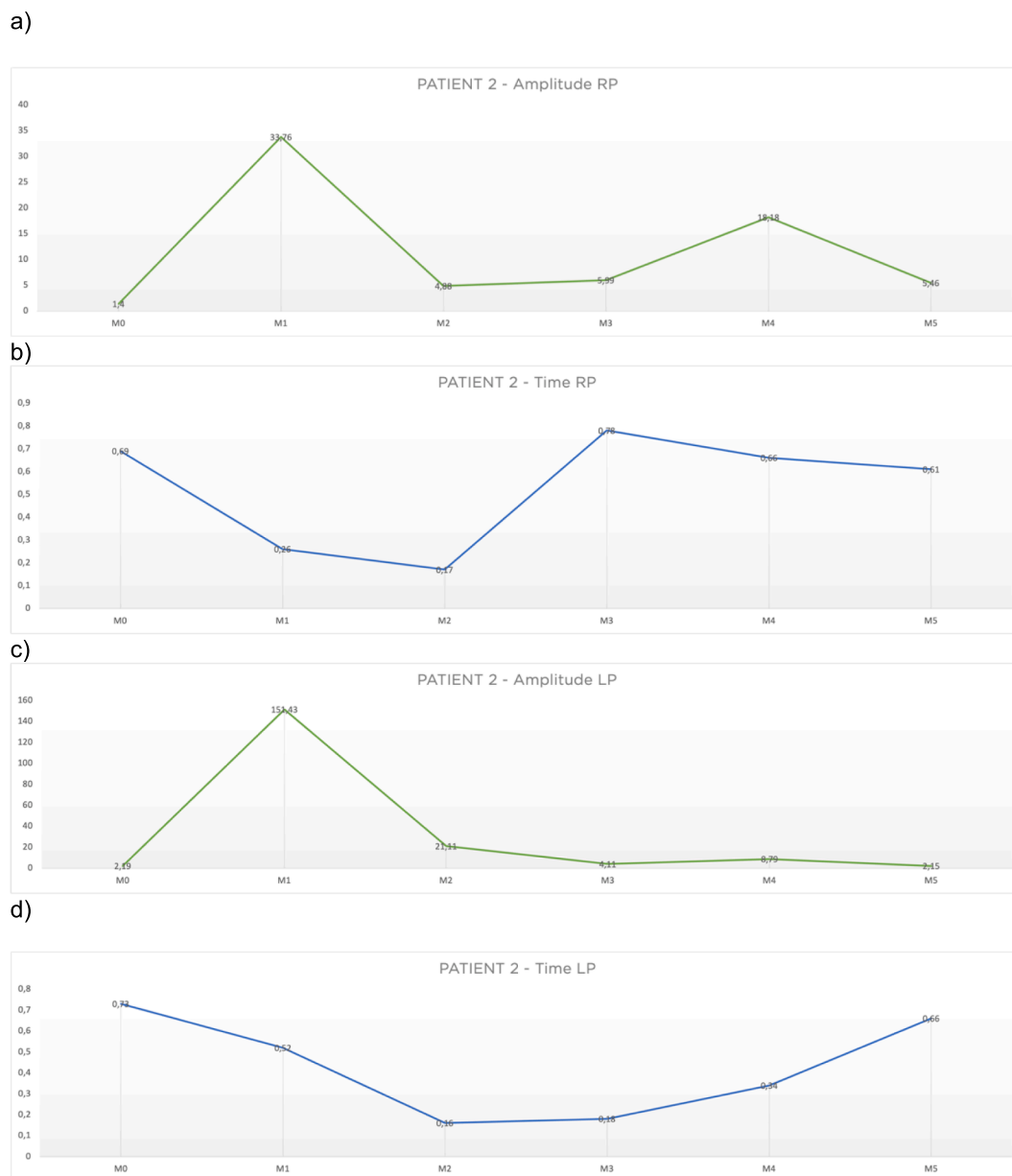


Fig. 5. Graphic of the progression of patient 1 a) amplitude and b) time – right side only.

or patients with Parkinson-plus syndromes, and secondary parkinsonism [27], patients with cardiac or renal insufficiency [28], and patients with Deep Brain Stimulation [29,30].

Additionally, we defined dropout criteria as (1) withdrawal of Informed Consent, (2) more than two absences from the intervention protocol, or (3) moderate to serious adverse effects.

2.2. Materials

In this study, a Biopac MP36 polygraph, along with a digital goniometer (Fig. 2) and reflex hammer from Biopac, was utilized to assess changes in the patellar reflex (source: Karger; Digital Commons). The goniometer demonstrated displacement during reflex stimulation, while the hammer recorded the moment of stimulation. These records allowed for the measurement of the time elapsed from stimulation to the onset of the reflex response.

The goniometer used was calibrated using the Biopac protocol, ensuring accurate measurements. Despite challenges like patient agitation, at least 5 stimulation moments were recorded for repeatability.

Three representative records were chosen, providing average values per reflex and patient. Due to patient limitations, the amplitude of reflex movement was recorded instead of degrees. The time taken for all reflexes was also measured, offering valuable data for analysis.

2.3. Procedures

After agreeing to participate in the study, participants were instructed to continue following the established medication plan based on their clinical condition. All patients were on medication and maintained a stable dose for at least three months without experiencing any adverse effects.

Each participant underwent three acupuncture sessions per week for four weeks (a total of 12 treatments). The study design included six evaluation time points (as described in Fig. 3), divided into three different phases. Each phase consisted of two moments of evaluation: before and after the treatment, separated by a therapy period of at least 15 days. Thus, M0, M2, and M4 referred to moments before an acupuncture treatment, while M1, M3, and M5 referred to results

Table 3
Results of effects of acupuncture in patient 1.

Evaluation moments	Outcomes				
	RP			LP	
	Amplitude (degrees)	Time (seconds)	Velocity (°/s)	Amplitude (degrees)	Time (seconds)
M1-M0	-2,40 ↓ROM ↓time	-0,01	-4,28	*	*
M3-M2	-1,19 ↓ROM ↑time	0,11	-2,79	*	*
M5-M4	-2,88 ↓ROM ↓time	-0,02	-4,38	*	*
M2-M0	0,02 ↑ROM ↑time	0,07	-0,94	*	*
M4-M2	0,56 ↑ROM ↑time	0,02	0,63	*	*
M3-M1	-1,17 ↓ROM ↑time	0,18	0,55	*	*
M5-M3	-1,13 ↓ROM ↓time	-0,11	-0,95	*	*
M4-M0	0,58 ↑ROM ↑time	0,09	-0,31	*	*

Legend: RP = Right Patellar; LP = Left Patellar. *: Evaluation was not possible.

immediately after a treatment session.

2.4. Evaluation

At each assessment point, both before and after the acupuncture treatment, a biomechanical evaluation of the reflexes was conducted using a digital acquisition system (Biopac Student Lab Pro – BSL 4.0 MP 36, Biopac Systems, Inc., USA) [31]. The examiner ensured the patient's skin was clean and devoid of any injuries. Subsequently, a goniometer receptor was applied parallel to the femur and peroneal alignment, forming a 90° angle with the axes (positioned at the knee joint). A tape was employed to secure the receptors, maintaining direct contact with the skin.

For measuring the patellar reflex (Knee Jerk), the patient was positioned in a relaxed and comfortable seated posture on a table, with the leg free to swing (Fig. 4). Following this, the patellar tendon was tapped, and the resulting quadriceps contraction (extension of the knee) was analyzed [32].

2.5. Acupuncture treatment

Before commencing acupuncture treatment, patients were given thorough explanations. During the treatment, they remained comfortably supine in a well-ventilated and calm environment. Participants wore comfortable clothing, exposing the knee, ankle, elbow, and wrist periarticular regions, and were recommended to wear shorts and tops, with bare feet. Researchers maintained hygiene standards, washing hands systematically and using sterile surgical gloves for each patient.

A standardized acupuncture protocol, following the Heidelberg Model of Traditional Chinese Medicine (TCM), was applied based on a previous study [23].

This model, that integrates contemporary medical-scientific knowledge with classical Chinese medicine concepts, was developed by Greten [33 34–36]. Needles (14 per subject per session) were inserted bilaterally and manually stimulated until achieving a marked *DeQi* effect [5]. All interventions were conducted by an acupuncturist with a master's degree in TCM and 3 years of clinical practice. Sterile disposable needles (0.25x0.25 mm) were used. Acupuncture protocol targeted specific acupoints based on WHO definitions, namely, *ST₃₄* (*Liáng Qiū*), *HT₃* (*Shào Hǎi*), *HT₇* (*Shén Mén*), *KI₃* (*Tai Xi*), *KI₇* (*Fù Liū*) e *SP₄* (*Gong Sūn*), and was administered 30 min after drug ingestion [37]. The intervention

lasted for 30 min [23].

3. Results

Table 1 summarizes the characterization of the four individuals of the sample.

The results for each evaluation point are detailed in Table 2.1. The heterogeneity observed in the results can be explained by the different disease degree and major symptoms of each patient. It's noteworthy that no adverse effects were reported for any of the treatments.

Regarding to the Table 2.2., all patients show a reduction in scores after the intervention/treatment.

Patients with more severe disease stages (PT1 and PT2) still have relatively high scores, but with a clear improvement. Patients with milder disease (PT3 and PT4) show more significant improvements, with PT4 reaching an almost normal score.

With the values obtained in the 6 evaluation moments (M0-M5), we analyzed four different outcomes:

A) The **acute effects** of a single acupuncture treatment, by means of the difference between results obtained after and before a clinical intervention → M1-M0, M3-M2 and M5-M4.

B) The **cumulative effects of acupuncture before a clinical intervention**, analyzing the difference between results obtained before treatments → M2-M0 and M4-M2.

C) The **cumulative effects of acupuncture after intervention**, analyzing the difference between values obtained after treatments → M3-M1 and M5-M3.

D) The **cumulative effects of the acupuncture protocol**, by means of the difference between values obtained before the treatment in the last moment of evaluation, and the first one → M4-M0.

Given the areflexia presented by these patients, we considered as improvement in clinical condition an increase in amplitude with a reduction in time, resulting in an increased speed of task execution. However, when analyzing the four outcomes, we observed an increase in amplitude with an increase in time, and a reduction in amplitude with a reduction in time. Considering that movement efficiency involves executing an action or motion with minimal energy and resource consumption, [38], the ratio amplitude/time was calculated. In our opinion this ratio is adequate to measure the efficiency of the movement and to better understand the results. A ratio greater than one indicates better efficacy and less than one, a reduction in the efficacy of the movement.

4. Case results

4.1. Patient 1

In Tables 1 and 2 are shown the characterization and results obtained for patient 1. Left patellar reflex of this patient could not be assessed due to the presence of osteosynthesis material (from prosthetic placement) in the left knee. Fig. 5 shows the progression of the patient in terms of (a) amplitude and (b) time.

The four outcomes analyzed for patient 1 are presented in Table 3. Regarding the outcome A, this patient tended to exhibit a reduction in the range of motion and time immediately after the acupuncture treatment. In this patient, the range of movement (ROM) only increased when a cumulative effect was involved (0,02° and 0,56° at M2-M0 and M4-M0, respectively).

With respect to outcome B, we found an increase in range with an increase in time (Table 3). Analyzing the velocity of the movement, an increase in the speed of the movement was found (Velocity = 0,63°/s at M4-M2).

With respect to outcome C, the clinical intervention tended to decrease the range of motion (-1,17° and -1,13° for M3-M1 and M5-M3, respectively). Regarding the outcome D, an increase in reflex range with an increase in time for movement execution was found. In this case, a light decrease in velocity (-0,31°/s) was also observed

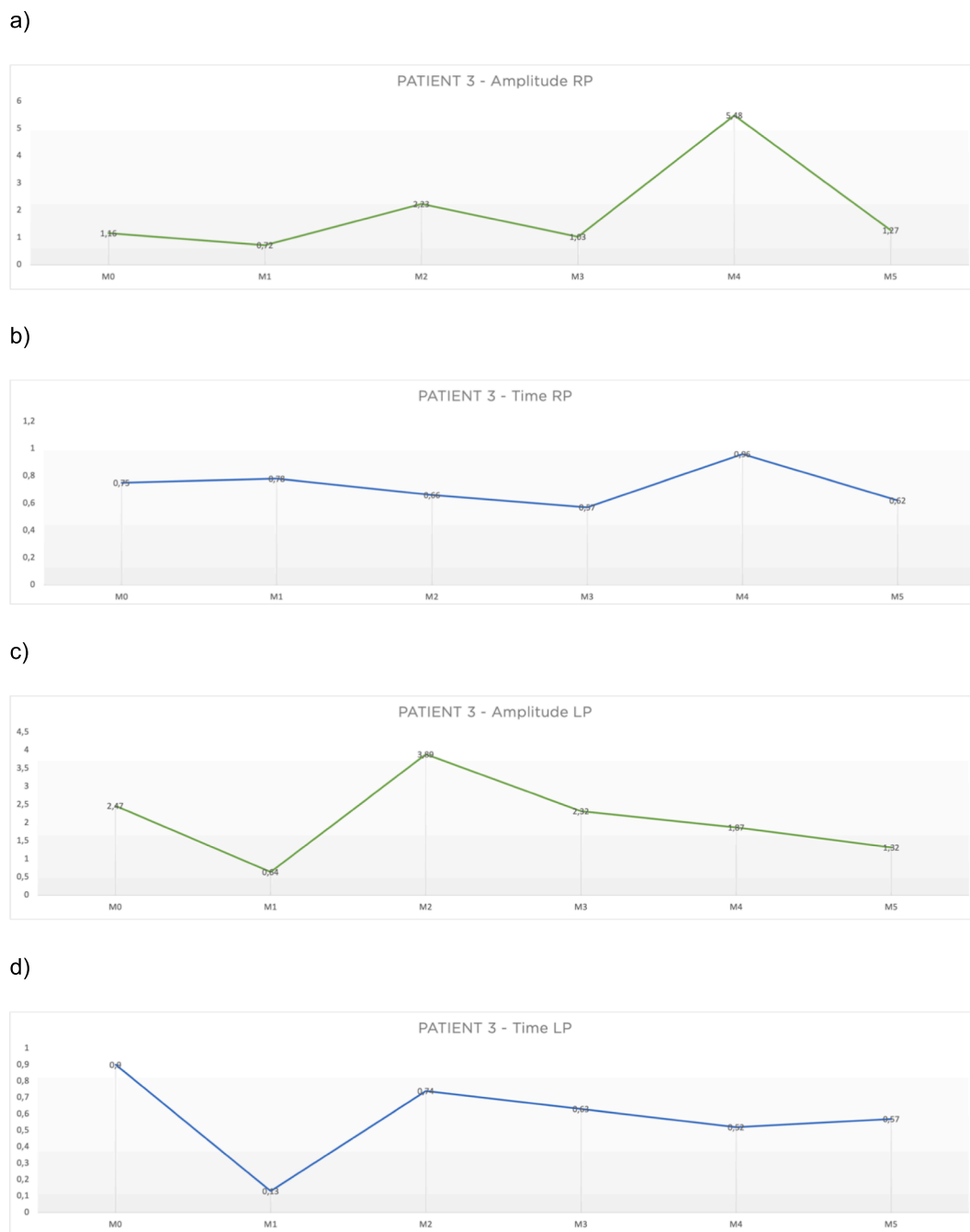


Fig. 6. Graphic of the progression of patient 2 – left (LP) and right side (RP).

(Table 3).

4.2. Patient 2

The characterization and results for the six evaluation moments for patient 2 are shown in Tables 1 and 2. In Fig. 6 the progression of the patient is represented in a graphic way: amplitude and time from the right side (a and b) and amplitude and time from the left side (c and d).

Table 4 shows the four outcomes analyzed for patient 2. Regarding the outcome A, we observed an increase in the range of motion immediately after the first treatment (M1-M0) on both sides ($32,36^\circ$ at RP and $149,24^\circ$ at LP) and improvements in the velocity also in both sides ($127,82^\circ/s$ and $288^\circ/s$, respectively), but a reduction in efficacy for the rest of the treatments (M3-M2 and M5-M4).

Concerning the cumulative effects of acupuncture before clinical

intervention (outcome B), we observed that the velocity increased with the first five treatments, mainly in the left side (the most affected) ($26,68^\circ/s$ in RP and $128,94^\circ/s$ in LP at M2-M0). However, when we analyzed cumulative effects after acupuncture treatment, (outcome C) a reduction in range on both sides was found (Table 4). It is noteworthy that the improvements found in outcome A and C, were more pronounced on the left side, which is the most affected side in this patient.

Concerning the outcome D, effects of the whole protocol, we found an increase in range with a reduction in time on both sides, what represents a clear improvement in reflex response (Table 4).

4.3. Patient 3

The characterization and results of all the evaluation moments for patient 3 are shown in Tables 1 and 2, respectively. In Fig. 7, the

Table 4

Results of acute effects of acupuncture in patient 2. Legend: RP = Right Patellar; LP = Left Patellar.

Evaluation moments	Outcomes					
	RP			LP		
	Amplitude (degrees)	Time (seconds)	Velocity ($^{\circ}/s$)	Amplitude (degrees)	Time (seconds)	Velocity ($^{\circ}/s$)
M1-M0	32,36 ↑ROM ↓time	-0,43	127,82	149,24 ↑ROM ↓time	-0,21	288,21
M3-M2	1,11 ↑ROM ↑time	0,61	-21,03	-17,00 ↓ROM ↑time	0,02	-109,10
M5-M4	-12,72 ↓ROM ↓time	-0,05	-18,59	-6,64 ↓ROM ↑time	0,32	-22,60
M2-M0	3,48 ↑ROM ↓time	-0,52	26,68	18,92 ↑ROM ↓time	-0,57	128,94
M4-M2	13,30 ↑ROM ↑time	0,49	-1,16	-12,32 ↓ROM ↑time	0,18	-106,08
M3-M1	-27,77 ↓ROM ↑time	0,52	-122,17	-147,32 ↓ROM ↓time	-0,34	-268,38
M5-M3	-0,53 ↓ROM ↓time	-0,17	1,27	-1,96 ↓ROM ↑time	0,48	-19,58
M4-M0	16,78 ↑ROM ↓time	-0,03	25,52	6,60 ↑ROM ↓time	-0,39	22,85

progression of the patient is represented in a graphic way: area and time from the right side (a and b) and area and time from the left side (c and d).

Table 5 presents the four outcomes analyzed for patient 3. Regarding the outcome A (immediate effects of acupuncture), there is a noticeable pattern of worsening the efficacy of the movement except for the M1-M0 at the left side ($2,18^{\circ}/s$).

Concerning the outcome B, we can note an improvement in amplitude, time and velocity during the initial assessment (M2-M0) for both sides (M2-M0 RP = $1,83^{\circ}/s$, M2-M0 LP = $2,51^{\circ}/s$) and at M4-M2 for the right side ($2,33^{\circ}/s$) (the most affected side) (Table 5). Regarding the outcome C (cumulative effects after clinical intervention), we observed that the efficacy of the movement improved at M5-M3 and M3-M1 in the right side ($0,24^{\circ}/s$ and $0,88^{\circ}/s$, respectively) and decrease in the left side ($-1,37^{\circ}/s$ and $-1,24^{\circ}/s$).

For outcome D, we observed (Table 5) that both sides experienced an improvement in movement speed ($4,16^{\circ}/s$ at right and $0,85^{\circ}/s$ at left side) although it was more pronounced at the most affected side, with also an enhancement in the range of motion ($4,32^{\circ}$).

4.4. Patient 4

The characterization and results of all the evaluation moments for patient 4 are shown in Tables 1 and 2. In Fig. 8 the progression of the patient is represented in a graphic way: area and time from the right side (a and b) and area and time from the left side (c and d).

In this patient moments M4 and M5 were not possible to evaluate due to equipment damage.

Table 6 presents the four outcomes analyzed for patient 4. Regarding the acute effects of acupuncture (outcome A), we observed an increase in amplitude and a reduction in time, with an increase in velocity ($23,71^{\circ}/s$ in RP and $603,12^{\circ}/s$ in LP at M3-M2, and $16,99^{\circ}/s$ in LP at M1-M0).

As for the cumulative effects of acupuncture before clinical intervention (outcome B), we observed that at the more affected side (right side), there was a decrease in both amplitude and time, while at the less affected side (left side), there was an improvement in amplitude, time and velocity ($1,04^{\circ}/s$). Regarding the cumulative effects of acupuncture after clinical intervention (outcome C), we observed an increase in amplitude with a reduction in time on both sides, with an improvement in velocity more pronounced on the left side ($22,17^{\circ}/s$ and $587,17^{\circ}/s$, respectively) (Table 6).

Outcome D could not be evaluated once again due to a lack of data collection at M4.

5. Discussion

The primary motor symptoms of parkinsonism, including slowness of movement (bradykinesia), muscle stiffness, and resting tremors, result from disruptions in the motor circuit of the basal ganglia due to the loss of dopaminergic neurons in the nigrostriatal pathway [39,40]. The depletion of dopamine in Parkinson's patients leads to an increased neuronal activity in the internal segment of the globus pallidus and the pars reticulata of the substantia nigra. This results in the inhibition of neurons in the thalamus and the pedunculopontine nucleus, leading to an enhanced gain in the globus pallidus pars externa-subthalamic nucleus-globus pallidus pars interna network and reduced activity in the "direct" corticostriatopallidal pathway. This imbalance contributes to the development of akinesia and rigidity [40,41].

It is believed that long-latency reflexes or decreased inhibition of the spinal Ib reflex are also mechanisms underlying rigidity [39–42]. Different studies revealed specific relationships of neuronal activity with movements of individual body parts and a correlation with direction, amplitude, and velocity [43].

Patients with PD commonly exhibit hyporeflexia, marked by a reduction in reflex movement amplitude, the joint's range of motion decreases, along with an increase in peak time [44]. These patients exhibit reduced sensitivity of polysynaptic reflexes in the extensor muscles of the leg, correlating with their postural instability. The reduction in proprioceptive reflex function can be partially compensated by changes in the intrinsic muscle stiffness [45]. Although the reflexes are primarily monosynaptic, there are many supraspinal pathways that modulate responses in terms of amplitude and latency [46]. In this sense, the patellar reflex is considered a monosynaptic reflex, involving only two neurons: a sensory neuron and a motor neuron, with a single synapse between them. The pathway of patellar tendon reflex response is illustrated in Fig. 8 [32,47]. The absence of a reflex response in these patients suggests central nervous system damage [48].

Although spinal reflex arcs bypass the brain to provide a rapid response, the descending corticospinal pathways modulate and refine the amplitude of the reflex arc. The deep tendon reflex arc is divided into an upper motor neuron (UMN) component and a lower motor neuron (LMN) component. Reflex responses increase in diseases of the upper motor neurons due to a lack of suprasegmental control, leading to conditions such as spasticity and rigidity [32,49,50]. Hyporeflexia is often indicative of a disease of the LMN, specifically affecting the peripheral nerve or the ventral (anterior) horn of the spinal cord at that level. Disease or disruption of the LMN results in a decreased or absent reflex, as the stimulus is not transmitted to the effector muscle. Additional features of LMN disease include the presence of flaccidity or

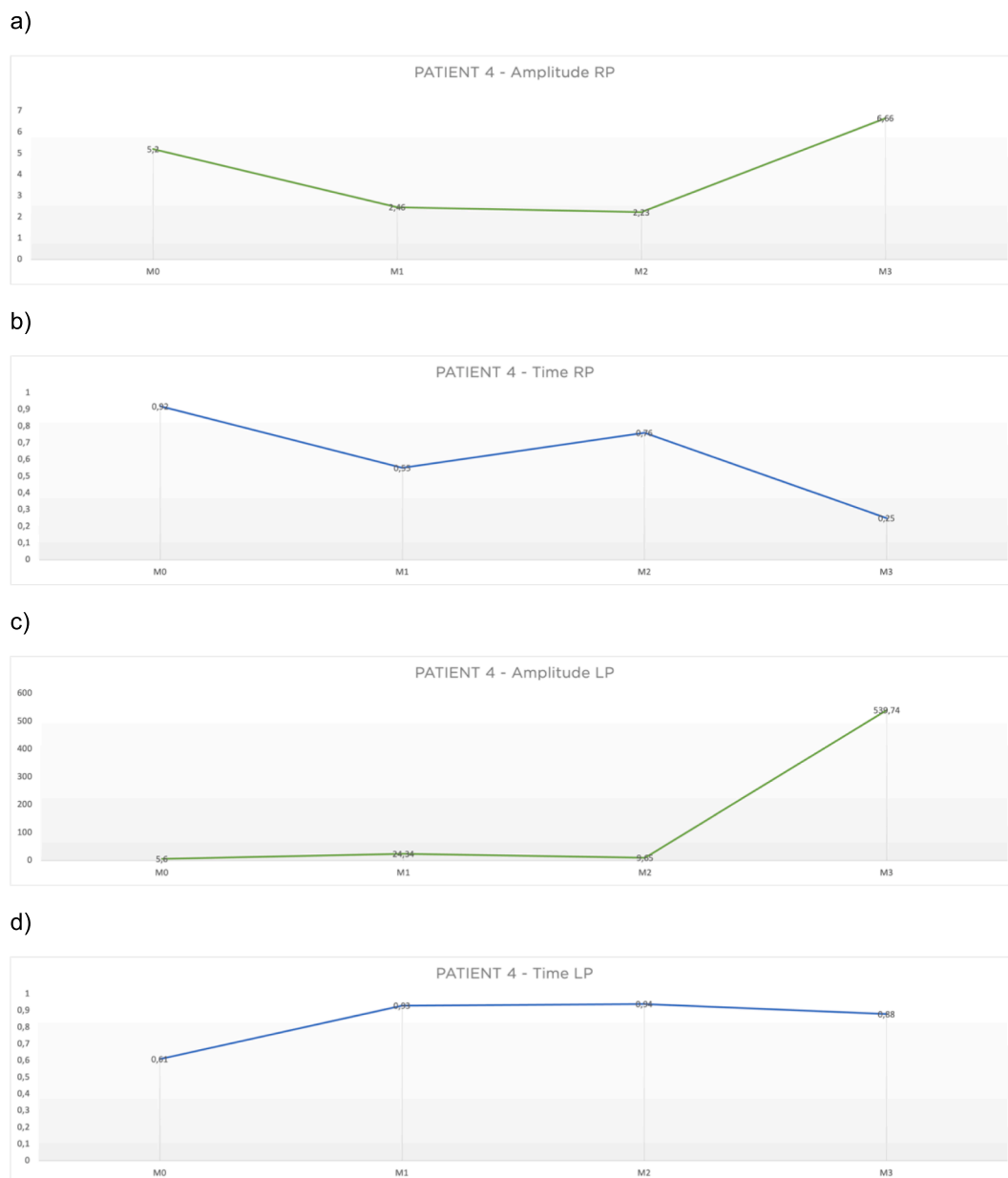


Fig. 7. Graphic of the progression of patient 3 – left (LP) and right side (RP).

decreased tone, weakness, fasciculations, and muscle atrophy [53].

There is evidence suggesting a relationship between changes in muscle tone and the speed and extent of joint movements. The swinging motion triggered by the patellar T reflex allows for the assessment of phasic stretching reflexes and physiological changes during passive stretching. Consequently, the speed and extent of muscle tone in Parkinson's rigidity can be examined together. The rigidity in Parkinson's disease involves a velocity-dependent aspect, and this shows a negative correlation with the rigidity scale [44].

Conventional pharmacological treatments fail to replicate the normal functioning of the dopaminergic system. Consequently, they do not restore a balanced interaction between corticostriatal pathways in the so-called direct and indirect routes, leading to the emergence of motor complications like dyskinesias [40]. Considering this, the current study was undertaken to explore the potential impact of integrative medicine, particularly acupuncture sessions maintained over a month, occurring three times a week. The aim was to observe if this approach could influence and shape the physical symptoms experienced by these

patients.

To address the subjectivity in the assessment of reflexes and introduce a quantitative and objective approach, we conducted a study with the assistance of Biopac [54] with E-Rehabilitation technology [55].

Regarding the choice of acupuncture points, we selected one that correspond to the quadriceps femoris muscle, the main knee extensors essential for maintaining an upright posture (ST34). It is known that during the pathology, individuals lose full knee extension, adopting a flexor posture of the lower limbs throughout the gait cycle. Due to decreased plantar flexion capability, the limb's propulsion phase is not executed, resulting in a reduction in forward thrust. As patients cannot induce it through the foot, they try to compensate by anteriorizing the trunk to overcome the deficit and achieve some forward transfer of the center of gravity [23]. Therefore, it makes sense to stimulate this muscle, which is also directly involved in the patellar reflex. Also, in the literature, the stimulation of this point has been associated with the activation of neural responses, by activating precentral gyrus and prefrontal cortex associated with PD [54–58].

Table 5
Results of acute effects of acupuncture in patient 3.

Evaluation moments	Outcomes					
	RP			LP		
	Amplitude (degrees)	Time (seconds)	Velocity (°/s)	Amplitude (degrees)	Time (seconds)	Velocity (°/s)
M1-M0	-0,44 ↓ROM ↑time	0,03	-0,62	-1,83 ↓ROM ↓time	-0,77	2,18
M3-M2	-1,20 ↓ROM ↓time	-0,09	-1,57	-1,57 ↓ROM ↓time	-0,11	-1,57
M5-M4	-4,21 ↓ROM ↓time	-0,34	-3,66	-0,55 ↓ROM ↑time	0,05	-1,28
M2-M0	1,07 ↑ROM ↓time	-0,09	1,83	1,42 ↑ROM ↓time	-0,16	2,51
M4-M2	3,25 ↑ROM ↑time	0,30	2,33	-2,02 ↓ROM ↓time	-0,22	-1,66
M3-M1	0,31 ↑ROM ↓time	-0,21	0,88	1,68 ↑ROM ↑time	0,50	-1,24
M5-M3	0,24 ↑ROM ↑time	0,05	0,24	-1,00 ↓ROM ↓time	-0,06	-1,37
M4-M0	4,32 ↑ROM ↑time	0,21	4,16	-0,60 ↓ROM ↓time	-0,38	0,85

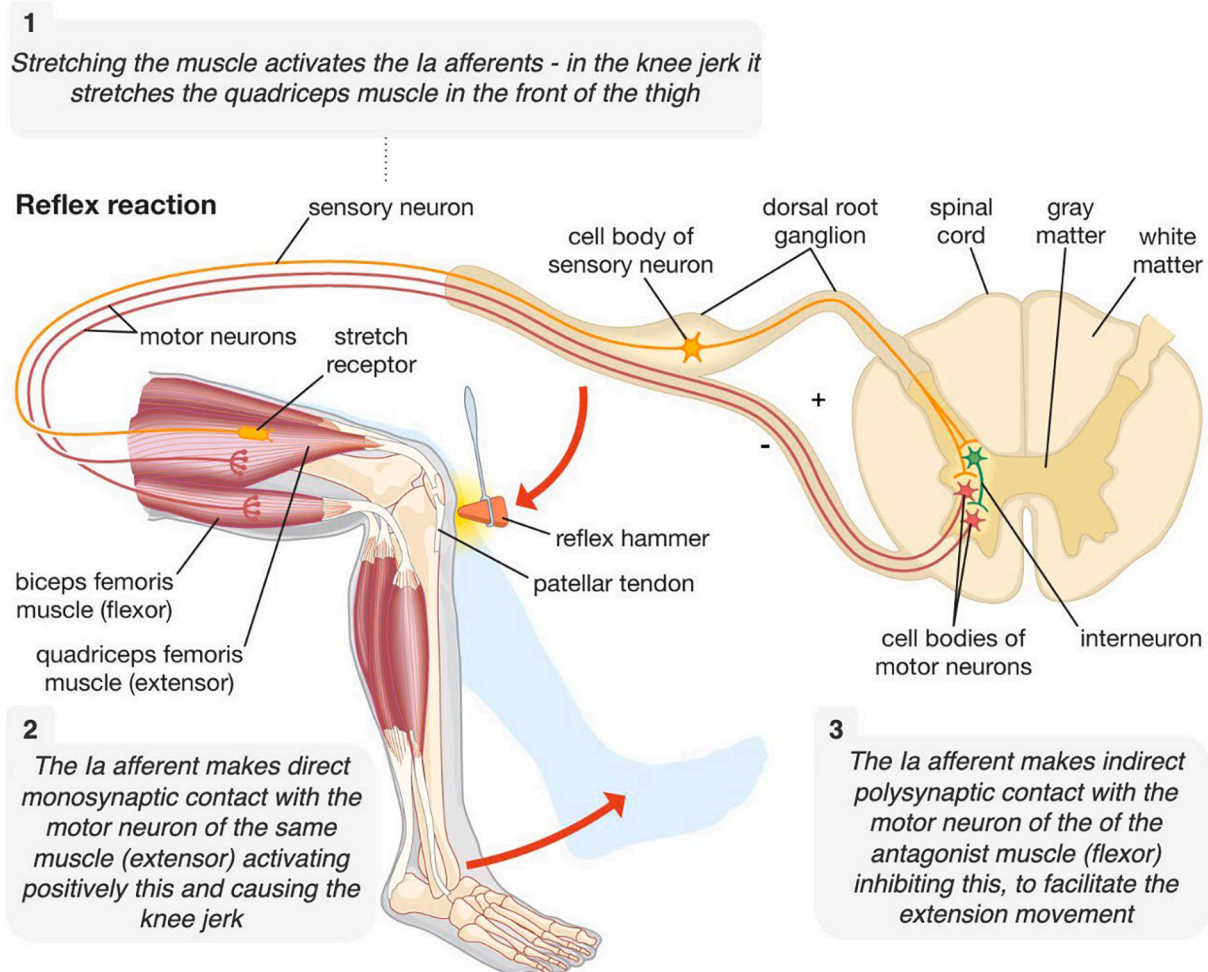


Fig. 8. Mechanism of the patellar tendon reflex response, adapted from [51,54,55]. 1- First phase; 2- Second phase; 3- Third phase (temporal sequence).

The remaining points were chosen based on a recent systematic review [59], and aim at treating the pathology itself. According to TCM principles, in Parkinson’s disease, the upward movement of the kidney does not reach the head and face due to renal deficiency and blockage of the water phase (KI3 and KI7). Thus, the heart, mirrored in the face, is blocked in its course, resulting in yang deficiency (HT3 and HT7), also

causing a blockage in the center (spleen and/or stomach) (SP4) [23,57].

Although the limitations of the study our findings suggest that acupuncture can have overall positive cumulative effects on normalizing the patellar reflex. In response to the underlying pathology, this improvement could be extended to the neural circuits related to the condition, leading to enhanced speed and amplitude of the patellar

Table 6
Results of acute effects of acupuncture in patient 4.

Evaluation moments	Outcomes					
	RP			LP		
	Amplitude (degrees)	Time (seconds)	Velocity (°/s)	Amplitude (degrees)	Time (seconds)	Velocity (°/s)
M1-M0	-2,74 ↓ROM ↓time	-0,37	-1,18	18,74 ↑ROM ↑time	0,32	16,99
M3-M2	4,43 ↑ROM ↓time	-0,51	23,71	530,09 ↑ROM ↓time	-0,06	603,12
M5-M4	* *	*	*	* *	*	*
M2-M0	-2,97 ↓ROM ↓time	-0,16	-2,72	4,05 ↑ROM ↑time	0,33	1,04
M4-M2	* *	*	*	* *	*	*
M3-M1	4,20 ↑ROM ↓time	-0,30	22,17	515,40 ↑ROM ↓time	-0,05	587,17
M5-M3	* *	*	*	* *	*	*
M4-M0	* *	*	*	* *	*	*

Legend: RP = Right Patellar; LP = Left Patellar. *: Evaluation was not possible.

reflex, along with possible improvements in various motor symptoms such as muscle rigidity and akinesia/bradykinesia. In accordance with these results, numerous studies reported that acupuncture treatments can ameliorated motor symptoms in patients with PD [10].

It is important to point out that the observed cumulative positive effects of our acupuncture protocol on improving the reflex arc, could reflect an adaptive (unconscious) peripheral response of the body. Two randomized clinical trials also emphasized similar findings, as a positive correlation was found between the improvement in Unified Parkinson's Disease Rating Scale (UPDRS-III) scores and the increase in weekly frequency of acupuncture treatments [12]. However, there are no literature assessing the effects of acupuncture on the knee jerk/patellar reflex in other pathologies, therefore further studies should follow.

Temporal parameters, encompassing factors like retention time, session duration, frequency, and overall treatment duration, play a crucial role in acupuncture effectiveness. However, these parameters vary depending on the specific disease conditions. Thus, determining the optimal temporal parameters for acupuncture holds considerable clinical significance [58,59]. Previous studies [60,61], have reported positive effects related to treatment duration and the subsequent improvement in clinical responses, consistent with the results found in the present investigation. In conclusion, within the spectrum of the four evaluated Parkinson's patients, a possible positive dose-response relationship between acupuncture's temporal parameters and its effects was observed [62]. Looking ahead it is hoped that additional studies will delve into the dose-response relationship of acupuncture. This exploration is crucial to determine the Minimum Therapeutically Beneficial Dose (MTB) of acupuncture [60].

Despite numerous high-quality randomized clinical trials investigating the therapeutic effects of acupuncture, the potential mechanisms exhibit noticeable heterogeneity [64]. Acupuncture appears to activate various brain amplitudes involved in pain regulation, processing, emotions, cognition, and other brain regions [65]. Different studies indicated that acupuncture seems to protect dopaminergic neurons against toxic insults and increase dopamine production in the brain by inducing release of neurotrophic factor, enhancing antioxidant agents, and inhibiting inflammation [10].

In our study we did not find any adverse events in none of the patients. According to different studies, acupuncture can be considered a safe and beneficial complementary approach in treating stroke [66], Parkinson's disease, and various neurological disorders [65–69]. It has been shown to stimulate both innate and adaptive immune responses, with its anti-inflammatory effects involving the activation of neural reflexes [70]. Lines of evidence also indicate that the regulation of

neuroendocrine and immune networks may be a common switch for acupuncture in different nervous system diseases [71]. With recent advances in physio pathological studies, there is now a great opportunity to gain insights into how acupuncture acts in modulating the nervous system [72].

Although the limitations of the present study concerning the reduced sample size and the limited outcomes analyzed, we consider that the results obtained are promising and justify the continuity of the study. We believe that the next step should involve conducting a large-scale study that could confirm the hypotheses raised here. Subsequent studies assessing other motor outcomes inherent to the process, such as nerve conduction velocity, electromyography of affected muscles, and functional magnetic resonance imaging studies, are of utmost importance for validating these findings.

6. Conclusion

This investigation focused on assessing the possible clinical effects of acupuncture in the behavior of patellar reflex of PD patients. Although the limitations of the study, our results let us conclude that 1) the methodology used in this study seems to be appropriated and reliable for the evaluation of the reflexes in Parkinson's patients and 2) Although the small sample size, we found some evidence of a possible influence of the acupuncture protocol used on the improvement of patellar reflex behavior. If these results are confirmed in large sample size studies, we anticipate possible improvements in gait parameters, alterations in motor and prefrontal cortex activity, and changes in neurotransmitter activity. Our results suggest the potential of acupuncture as a complementary treatment for motor symptoms of PD patients. However, it is crucial to conduct further well-designed clinical trials with larger sample sizes to solidify and substantiate these preliminary findings.

Providing solid evidence could let PD patients that experience hyporeflexia, to consider acupuncture as a potential intervention to prevent further deterioration of their motor condition, as part of a multidisciplinary treatment approach for PD patients.

Ethical Considerations

The present study was approved by the Ethics Committee of the Abel Salazar Institute of Biomedical Sciences of the University of Porto (reference no GS/HCC/9). Data collection was also authorized by the CHUDSA/ICBAS committee that authorized the personal data treatment, according to the law.

All data collected were obtained while safeguarding the privacy of

participants, and were treated confidentially, maintaining anonymity, to ensure the protection of all data accordingly.

Author Disclosure Statement

None of the authors has a financial or property stake in the Heidelberg model.

CRedit authorship contribution statement

Catarina Ramos Pereira: Writing – original draft, Methodology, Investigation, Conceptualization. **Jorge Machado:** Writing – review & editing, Validation, Supervision, Conceptualization. **Begoña Criado:** Writing – review & editing, Validation, Supervision, Formal analysis, Conceptualization. **Rubim Santos:** Writing – review & editing. **Ana Mafalda Reis:** Validation. **Bruno Ramos:** Software, Methodology, Investigation, Formal analysis, Data curation. **Maria João Santos:** Validation. **Henry Johannes Greten:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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