Biomechanical analysis of an upper limb rehabilitation process using optoelectronic cameras in patients with Parkinson's disease.

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BIOMEDICAL ENGINEERING

Context

- Parkinson's disease (PD) is a degenerative disease, and it has a significant impact on society [1].
- PD is the second most common neurodegenerative disease in North America and Europe (2-3%) [2].
- In 2010, (1.1 million) people in USA had PD. By 2030, is expected to increase to 1.8 million and 2.5 million by 2050 [3].

- The most common motor symptoms are
  - ✓ Tremor (69-75%) [3-4].
  - ✓ Rigidity [3].
  - ✓ Akinesia or bradykinesia [3].
  - ✓ Postural instability [3].

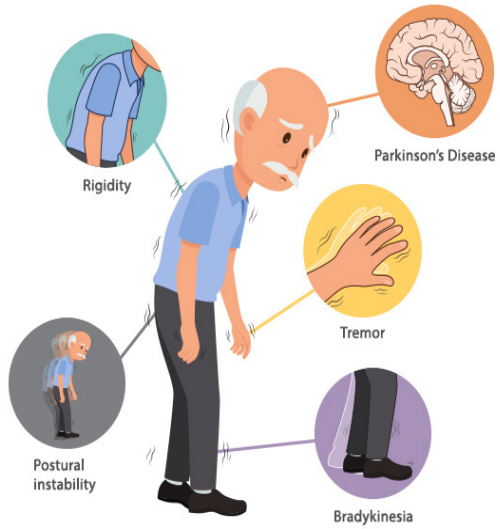

Fig 1. Motor symptoms. Taken from: https://mobile.hksh.com/en/physio-our-services/neurological-rehabilitation/parkinsons-disease

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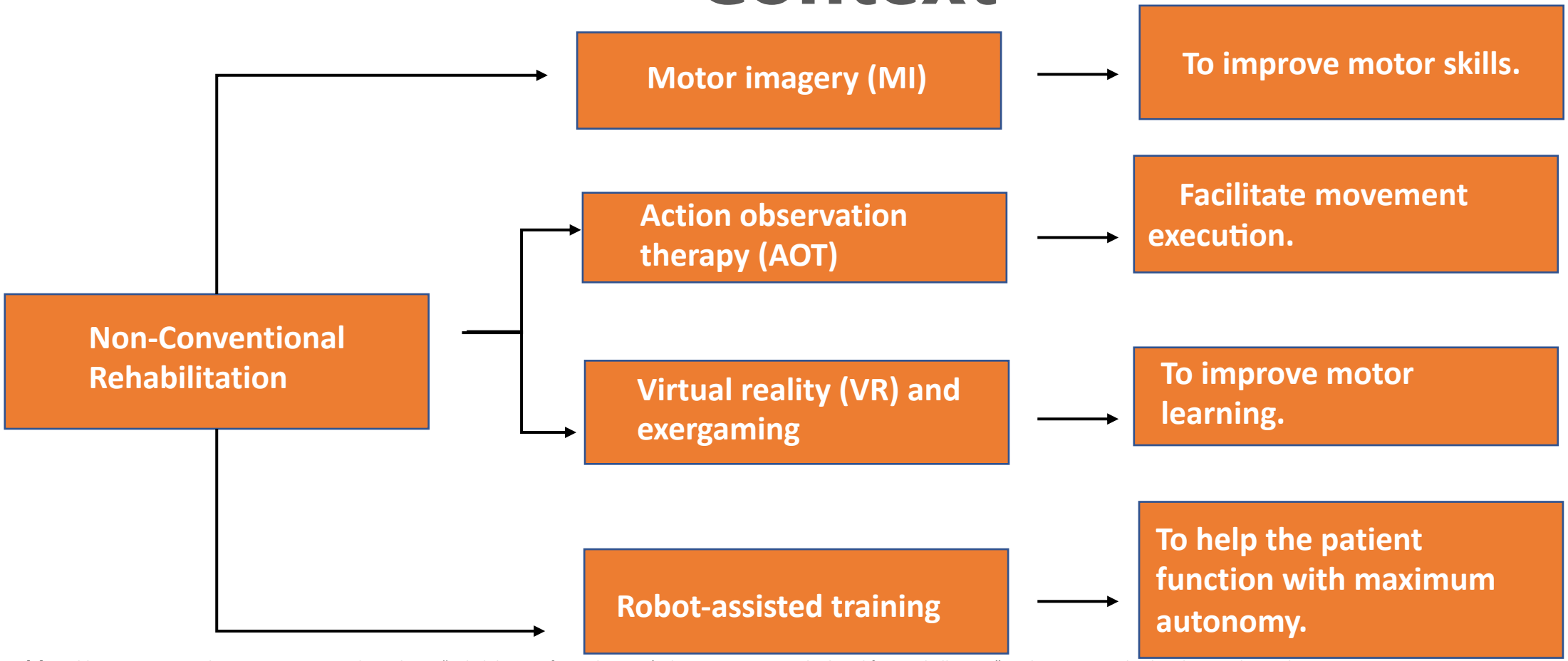
Context



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Context

Found in the literature:

To evaluate the learning effect and reliability with ArmeoSpring

To investigate changes in upper extremity motor performance.

To evaluate the upper extremity.

What is missing in the literature?

Few studies that incorporates robotic rehabilitation in PD.

The tests performed by patients are usually grasping and reaching exercises.

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Objectives

General Objective:

To perform a biomechanical analysis of an upper limb before and after of rehabilitation process with Armeo Spring ® Exoskeleton in patients with PD using a motion capture system.

Specific Objectives:

1. To perform the extraction of clinical parameters of interest such as maximum angles, angular velocities, execution times and joint range of motion from motion capture data.

2. To compare the results obtained in kinematics with the literature of upper limb rehabilitation in PD.

3. To evaluate the efficacy of robotic rehabilitation therapy in a group of patients with PD, by performing a statistical analysis.

4. To understand which joint and degree of freedom is most affected in patients with PD.

Methodology

Participants

- This study was carried out with 12 patients with PD (7 women and 5 men).
- All patients had PD measured with the Hoehn and Yahr scale (HY).

Pacient	Age (years)	Height (m)	Weight (kg)	Hoehn and Yahr
1	79	1.60	65	4
2	64	1.44	60	3
3	61	1.55	60	3
4	75	1.66	72	2
5	63	1.60	60	2
6	69	1.56	79	3
7	73	1.44	60	3.5
8	59	1.58	57	3
9	75	1.60	65	3
10	81	1.70	60	3
11	68	1.53	44	4*
12	65	1.68	82	3
	69.33±7.21	1.57±0.08	63.66± 10.19	

Table 1. Anthropometric characteristic of patientes with PD.

Methodology

Equipment and experimental procedure

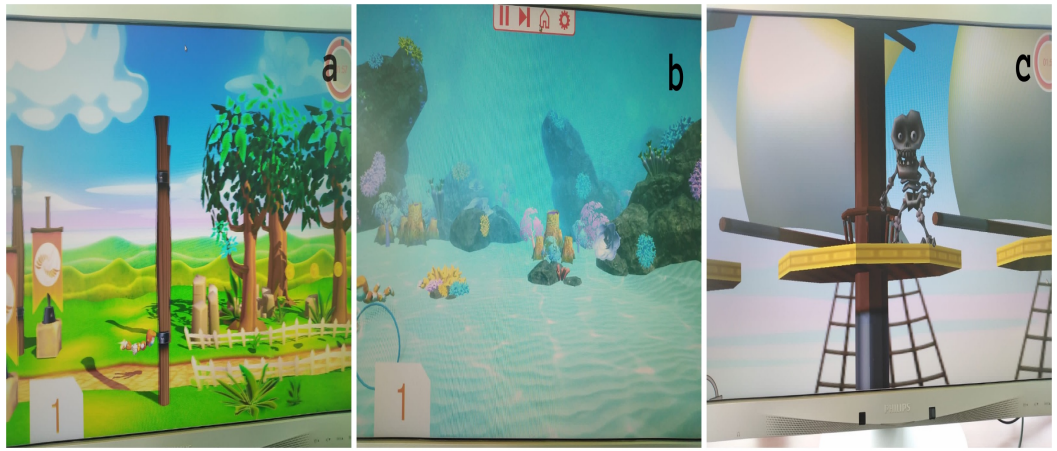

Fig 3. Figure (a) shows the interface of the high flying games, figure (b) shows the interface of the clean the ocean game, and figure (c) shows the interface of the pirates games.

Fig 4. Rehabilitation theraphy: Figure (a) patients are observed performed rehabilitation therapy, and figure (b) and (c) patients are observed performed the therapeutic games.

Methodology

Movement Analysis Assessment

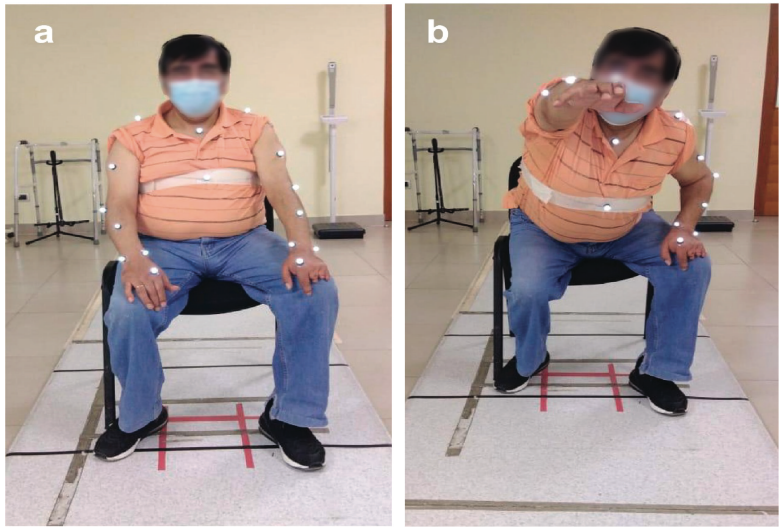

Fig 5. Maximum forward Reach Test sequence: Figure (a) shows the initial position, and figure (b) shows the final position.

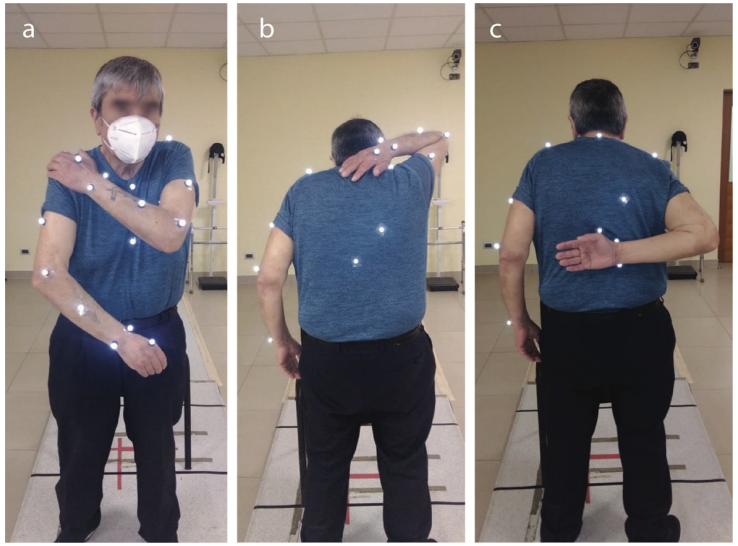

Fig 6. The Apley Scratching Test sequence: Figure (a) shows action 1 of the Apley scratch test. In figure (b), action 2 is observed. In the figure (c), action three is observed.

Fig 7. Box and Block Test.

Methodology

Definition of variables

- Maximum angles
- Range of Motion
- Execution time
- Angular Velocity.

Data analysis

- Wilcoxon Test

Results and discussion

Maximum Forward Reach Test

More affected upper limb

Less affected upper limb

Table 4.1: Maximum angles obtained for the more and less affected upper limb in the Maximum Forward Reach Test before and after the rehabilitation therapy.

Joint	Movement	Maximum angle before RT(°) MA UL	Maximum angle after RT(°) MA UL	p-Value	Maximum angle before RT(°) LA UL	Maximum angle after RT(°) LA UL	p-Value
Shoulder	Flexion	60.42 ±9.00	66.08±10.84	0.27	61.02±10.02	66.17±7.60	0.13
	Extension	9.18±4.37	11.62±10.72	0.98	11.53±8.58	13.32±6.66	0.27
	Adduction	107.09±21.77	126.85±17.8	**p≤0.05**	109.57±26.06	119.30±13.99	0.27
	Abduction	15.16±8.70	14.82±7.34	0.62	11.81± 8.60	13.99±6.58	0.18
	Int. Rot.	35.79±12.40	44.27±13.85	0.23	38.72±15.38	43.35±12.60	0.27
	Ext. Rot.	60.33±19.58	82.25±40.63	**p<0.05**	62.98±22.14	71.19±33.79	0.37
Elbow	Flexion	81.06±9.88	79.30±16.25	0.98	79.16±14.98	76.99±10.99	0.98
	Extension	32.14±9.66	26.13±5.13	**p≤0.05**	34.65±8.41	28.31±5.09	**p<0.05**
Wrist	Flexion	30.75±10.68	44.12±12.67	**p<0.05**	33.66±12.97	47.87±13.5	**p≤0.05**
	Extension	16.59±9.48	15.93±8.76	0.92	13.66±8.00	15.95±11.23	0.43
Forearm	Pronation	144.13±22.40	154.16±22.05	0.27	142.99±19.86	152.90±17.57	0.16
	Supination	117.59±20.08	114.26±23.40	0.92	117.20±19.25	123.25±14.80	0.32

Table 4.7: Execution time of the Maximum Forward Reach Test before and after the rehabilitation therapy.

Limb	Execution Time before RT (s)	Execution Time after RT (s)	p-Value
Less affected UL	8.45 ± 2.58	10.26 ± 2.70	0.20
More affected UL	8.18 ± 2.59	11.17 ± 3.19	**p≤0.05**
p-Value	0.57	0.14	

Table 4.3: RoM obtained for the more and less affected upper limb in the Maximum Forward Reach Test before and after the rehabilitation therapy.

Joint	Movement	RoM before RT(°) MA UL	RoM after RT(°) MA UL	p-Value	RoM before RT(°) LA UL	RoM after RT(°) LA UL	p-Value
Shoulder	Flex-Ext	69.61±9.98	77.71±17.57	0.20	72.55±13.29	79.50±11.13	**p≤0.05**
	Add-Abd	122.25±24.78	141.68±13.49	**p<0.05**	121.38±31.17	133.30±12.01	0.41
	Int/Ext Rot	97.92±21.09	126.52±40.22	0.36	101.70±23.66	114.54±29.19	0.27
Elbow	Flex-Ext	113.20±15.27	105.43±17.92	**p<0.05**	113.82±19.35	105.30±14.39	0.12
Wrist	Flex-Ext	47.35±18.48	60.05±17.35	**p≤0.05**	47.32±18.84	63.82±22.03	0.06
Forearm	Pron-Sup	261.73±39.43	268.42±38.66	0.96	260.20±37.46	276.16±29.09	0.2

Table 4.6: Angular velocities obtained for the more and less affected upper limb in the Maximum Forward Reach Test before and after the rehabilitation therapy.

Joint	Movement	Ang vel. before RT(rad/s) MA UL	Ang vel. after RT(rad/s) MA UL	p-Value	Ang vel. before RT(rad/s) LA UL	Ang vel. after RT(rad/s) LA UL	p-Value
Shoulder	Flex-Ext	221.37±87.54	157.81±41.20	**p<0.05**	268.97±162.06	174.29±58.35	**p≤0.05**
	Add-Abd	308.77±129.17	294.65±152.21	0.46	347.47±104.67	295.93±103.43	0.24
	Int/Ext Rot	343.75±136.10	298.41±167.40	0.36	363.40±61.78	336.57±137.63	0.63
Elbow	Flex-Ext	197.99±64.51	168.54±73.53	0.17	177.21±50.29	196.67±90.34	0.32
Wrist	Flex-Ext	146.13±83.44	170.19±111.23	0.63	157.89±66.48	188.05±109.39	0.83
Forearm	Pron-Sup	180.03±109.45	174.58±114.57	0.83	209.85±118.38	305.51±425.23	0.98

Results and discussion

More affected upper limb

Less affected upper limb

Apley Scratching Test

Table 4.8: Maximum angles obtained for themore and less affected limb in the Apley Scratching Test before and after the rehabilitation therapy.

Joint	Movement	Maximum angle before RT(°) MA UL	Maximum angle after RT(°) MA UL	p-Value	Maximum angle before RT(°) LA UL	Maximum angle after RT(°) LA UL	p-Value
Shoulder	Flexion	67.47±10.57	62.58±11.28	0.23	58.39±7.46	63.97±9.49	0.27
	Extension	37.34±8.63	42.61±18.81	0.27	35.09±11.04	47.17±9.48	**p≤0.05**
	Adduction	96.89±20.79	90.25±26.19	0.62	103.94±21.75	86.30±20.49	0.06
	Abduction	17.16±9.85	19.74±19.31	0.98	17.95±13.07	14.04±14.68	0.55
	Int. Rot	104.58±12.91	94.18±27.36	0.32	99.21±22.31	99.13±13.59	0.76
	Ext. Rot	62.72±31.41	65.53±36.93	0.92	65.17±29.82	52.14±34.65	0.37
Elbow	Flexion	144.08±11.49	155.20±10.86	0.10	136.14±26.93	153.12±6.95	**p≤0.05**
	Extension	54.86±18.34	68.92±14.09	**p<0.05**	4.23±17.50	65.42±13.77	0.10
Wrist	Flexion	49.42±13.84	41.08±23.20	0.16	48.42±11.74	39.17±10.53	0.13
	Extension	21.57±22.28	16.49±10.65	0.49	14.06±13.53	16.61±13.89	0.32
Forearm	Pronation	151.01±20.51	140.16±18.14	0.32	144.96±7.33	147.21±5.43	0.32
	Supination	65.57±46.82	55.01±51.99	0.55	65.96±39.96	75.63±46.62	0.49

Table 4.12: Execution time of the Apley Scratching Test before and after the rehabilitation therapy.

Limb	Execution Time before RT (s)	Execution Time after RT (s)	p-Value
Less affected UL	13.57 ±3.88	14.33 ± 3.54	0.92
More affected	14.15 ±4.73	13.69± 4.77	0.67
p-Value	0.76	0.84	

Table 4.10: RoM obtained for the more and less affected upper limb in the Apley Scratching Test Test before and after the rehabilitation therapy.

Joint	Movement	RoM before RT(°) MA UL	RoM after RT(°) MA UL	p-Value	RoM before RT(°) LA UL	RoM after RT(°) LA UL	p-Value
Shoulder	Flex-Ext	99.92±14.98	110.08±26.29	0.23	99.06±12.56	105.56±12.02	0.27
	Add-Abd	113.35±20.25	109.99±33.35	0.84	119.40±28.64	101.25±25.86	0.23
	Int/Ext Rot	167.38±29.72	159.71±42.84	0.62	164.38±42.39	151.28±33.20	0.49
Elbow	Flex-Ext	198.95±24.73	224.12±14.71	**p<0.05**	190.37±40.24	218.54±14.51	**p≤0.05**
Wrist	Flex-Ext	70.99±24.81	57.57±23.61	0.32	62.48±21.55	57.57±23.61	0.62
Forearm	Pron-Sup	216.58±62.53	195.17±59.54	0.37	210.93±40.93	222.84±49.72	0.49

Table 4.13: Angular velocities obtained for the more and less affected upper limb in the Apley Scratching Test before and after the rehabilitation therapy.

Joint	Movement	Ang vel. before RT (rad/s) MA UL	Ang vel. after RT (rad/s) MA UL	p-Value	Anr vel. before RT (rad/s) LA UL	Ang vel. after RT (rad/s) LA UL	p-Value
Shoulder	Flex-Ext	268.33±61.99	278.65±121.18	0.84	255.35±62.73	302.99±107.84	0.37
	Add-Abd	332.83±82.32	300.05±113.42	0.55	359.73±120.25	341.01±145.65	0.84
	Int/Ext Rot	481.65±123.19	423.46±167.68	0.37	495.89±106.61	526.74±193.02	0.76
Elbow	Flex-Ext	337.64±92.53	278.91±141.07	0.23	325.88±84.38	362.50±157.70	0.69
Wrist	Flex-Ext	389.91±231.02	235.95±181.37	0.23	345.60±152.16	361.73±208.15	0.98
Forearm	Pron-Sup	547.49±257.12	452.64±340.87	0.43	431.06±122.47	577.03±275.74	0.13

Results and discussion

More affected upper limb

Less affected upper limb

Box and Block Test

Table 4.15: Maximum angles obtained for the more and less affected limb in the Box and Block Test before and after the rehabilitation therapy.

Joint	Movement	Maximum angle before RT (°) MA UL	Maximum angle after RT (°) MA UL	p-Value	Maximum angle before RT (°) LA UL	Maximum angle after RT (°) LA UL	p-Value
Shoulder	Flexion	54.95±3.18	52.71±6.97	0.84	60.66±7.64	55.87±12.31	0.43
	Extension	21.35±5.74	23.66±8.43	0.31	30.52±8.17	25.16±5.74	0.15
	Adduction	50.20±14.58	54.39±18.57	0.84	50.48±10.98	60.93±26.23	0.68
	Abduction	18.60±6.00	13.09±3.66	0.15	19.75±8.74	17.35±6.63	0.56
	Int. Rot	18.40±9.56	20.45±8.63	0.68	28.97±5.88	21.60±7.88	0.21
	Ext. Rot	20.13±7.69	16.75±8.88	0.43	0.85±6.72	20.48±14.12	**p≤0.05**
Elbow	Flexion	100.64±2.26	108.39±6.87	**p≤0.05**	3.77±14.91	107.89±5.68	**p≤0.05**
	Extension	49.83±11.53	55.83±4.47	0.21	48.18±13.05	58.38±4.65	0.15
Wrist	Flexion	34.51±8.99	45.51±9.33	**p≤0.05**	34.47± 8.39	32.61±12.29	0.84
	Extension	7.72±7.26	8.91±13.28	0.31	11.66±8.53	10.38±10.52	**p≤0.05**
Forearm	Pronation	145.25±15.00	153.23±14.44	0.68	133.14±25.40	151.47±15.36	0.06
	Supination	105.05±9.00	104.93±7.61	0.95	82.40±28.92	105.73±6.23	**p≤0.05**

Table 4.17: RoM obtained for the more and less affected upper limb in the Box and Block Test before and after the rehabilitation therapy.

Joint	Movement	RoM before RT(°) MA UL	RoM after RT(°) MA UL	p-Value	RoM before RT(°) LA UL	RoM after RT(°) LA UL	p-Value
Shoulder	Flex-Ext	76.31±5.99	76.37±14.03	0.98	91.18±13.65	81.03±16.66	0.31
	Add-Abd	68.80±19.79	67.49±21.17	0.98	70.24±16.67	78.28±29.29	0.84
	Int/Ext Rot	38.53±7.22	37.21±10.01	0.98	39.82±6.56	42.08±14.82	0.82
Elbow	Flex-Ext	150.48±12.43	164.22±9.23	**p≤0.05**	141.95±22.93	166.27±7.31	**p≤0.05**
Wrist	Flex-Ext	42.23±13.99	54.43±15.18	0.43	46.13±14.73	43.00±9.69	0.97
Forearm	Pron-Sup	250.31±20.86	258.17±13.44	0.84	215.54±52.58	257.20±18.86	**p≤0.05**

Table 4.19: Angular velocities obtained for the more and less affected upper limb in the Box and Block Test before and after the rehabilitation therapy.

Joint	Movement	Ang vel. before RT (rad/s) MA UL	Ang vel. after RT (rad/s) MA UL	p-Value	Anr vel. before RT (rad/s) LA UL	Ang vel. after RT (rad/s) LA UL	p-Value
Shoulder	Flex-Ext	135.45±40.71	206.61±141.46	**p≤0.05**	147.05±39.42	247.93±179.12	**p≤0.05**
	Add-Abd	115.84±80.36	189.18±74.71	0.21	83.49±30.13	103.25±71.32	**p≤0.05**
	Int/Ext Rot	211.38±111.14	253.75±53.30	0.43	180.22±21.89	286.84±122.08	0.15
Elbow	Flex-Ext	343.89±150.72	313.36±53.03	0.68	246.03±76.08	302.31±84.69	0.21
Wrist	Flex-Ext	222.15±93.57	298.72±84.58	**p≤0.05**	170.95±65.59	213.51±65.64	**p≤0.05**
Forearm	Pron-Sup	310.21±157.56	372.47±133.96	0.68	336.27±189.87	286.43±133.76	0.84

Conclusion

- Armeo Spring ® Therapy as complementary tools in Parkinson's rehabilitation therapies has been shown to improve the range of motion, maximum angles, and angular velocities of more and less affected upper limbs. In the Maximum Reach test, the most affected joints were the shoulder, elbow and wrist because, depending on the nature of the test, differences in the elbow and shoulder joints were to be expected. In the Apley Scratching Test, the most affected joints were the elbow joint. Still, no articles related to Apley scratching and kinematic analysis in Parkinson’s patients were found in the literature. Regarding the Box and Block Test, the most affected joints were the elbow. However, it was expected that this test would have the wrist as the most affected extremity.

Future Work

Short-Term

- Compare with a healthy control group.
- Graphical analysis.
- kinematic analysis of the last cut of the Project.

Large-Term

- Analyze the ADLs.

Thank you so much!